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IMPERVIOUS LININGS IN SUBSURFACE SOILS

V. I. Shrag, *The Republic State Institute for Design and Planning of Water Resources and Reclamation Development*

SEEPAGE losses from irrigation canals, reservoirs and ponds often complicate the effective use of irrigation systems and reservoirs.

A result of these losses is a sharp decrease in the efficiency of the canals. There is a rise in the ground water and, in a considerable number of cases, the soil becomes waterlogged and saline, while the reservoirs remain dry when the water requirement is greatest. To control this unfavorable phenomenon a large number of more or less effective devices have been developed for decreasing seepage into the subsoil. These include primarily the following:

a) Solonetzation, which causes a two- to threefold decrease in seepage (in high-carbonate bed material and that with a coarse texture, solonetzation does not produce any noticeable effect);

b) Artificial gleying of fine-textured bed material by applying organic material to the soil surface;

c) Concrete topping, which is rather expensive to construct.

Other methods used are: the application of clay, tar or silicate, compacting the canal bottom, sedimentation, formation of hydrophobic films, and other devices of widely varying effectiveness, cost and duration (2, 4, 5).

In this case we propose a different method to control seepage losses. The method was developed in the laboratory of the Rosgiprovodkhoz.[1]

It should be noted that the above list of devices for seepage control does not include an attempt to form an impermeable lining in the soil itself, such as is formed under natural conditions. In addition, there is a well-known phenomenon consisting in the development within the soil of an illuvial stratum at a relatively shallow depth below the surface under the influence of biochemical processes. The form and extent of the illuvial process in soils is extremely varied. Thus, for example, in the podzolic zone an ortsand layer develops at a depth of 60 to 100 cm. in sandy and sandy loam soils, while in finer-textured soils of the same type (but at shallower depths) a compact ortstein pan may arise; and with excessive moisture a mixed ortstein layer often occurs (the "iron-pan soils" of Williams, 1). In all cases the illuvial stratum is of finer texture because of the eluviated colloids, so that it is considerably less permeable than the strata lying above and below it.

In spring and during the rainy period excessive moistening occurs in soils with a pronounced illuvial stratum (for example, in podzolic soils). Such moisture often forms surface water pools. When this surface water is especially abundant and the illuvial and gleying processes are intense, large areas become water-logged to the point of forming superficial bogs, even though the ground water may be at a considerable depth.

There is in some cases a favorable factor (6), in addition to this unfavorable aspect of illuvial soil formation.

The existence of an illuvial stratum is sometimes of great practical importance, often determining which system of reclamation and agricultural practices is required. Further, considering that the formation of soil interlayers (which causes a sharp decrease in the seepage characteristics of the subsurface material) is a natural phenomenon, we should consider the possibility of finding ways for naturally regulating or, in some cases, copying this natural process. When an illuvial stratum is the basic cause of the supersaturation of the surface soil, this stratum may be destroyed by deep subsoiling with appropriate implements (for example, a Mal'tsev plow), thus considerably increasing the circulation of water within the soil.

It is somewhat more difficult to resolve the question of how to use artificial means to create a lining within the soil which could significantly decrease the seepage rate of the water into the surrounding soil. Such an installation would be of great practical importance in the construction of ponds, reservoirs and canals in highly per-

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[1] Rosgiprovodkhoz-Respublikanskiy gosudarstvennyy institut po proyektirovaniyu vodokhozyaystvennogo i meliorativnogo stroitel'stva (Republic State Institute for Design and Planning of Water Resources and Reclamation Development).

TABLE 1

Results of experiments in decreasing the percolation of water through Kamenskiy tubes

Treatment	Nature of experiment	No. of days from beginning of expt.	Percolation rate, meters per day		Decrease in percolation vs. control
			Control	Experiment	
1	Cement layer in sand	2	27	5.6	4.8 times
2	Layer of 1:1 mixture of cement and sand in sand	6	16.7	1.0	16.7 "
3	Layer of 1:3 mixture of cement and fine silty sand	8	7.2	0.4	18 "
3a	Same as 3 but with 2 g. of clay suspension added	18	2.5	0.1	25 "

meable subsurface materials. On the basis of these considerations we set up the following preliminary experiments.

First Series

Kamensky tubes 3.7 cm. in diameter with working parts 20 cm. high were filled with sand. In the tubes serving as controls, sand was filled to a depth of 12 cm., while in the experimental tubes there was first an 8 cm. layer of sand, then a layer of 1.5 mm. of dry cement or cement mixed with sand (since the cross-sectional area of the tube was 9 cm.^{2}, this amounted to 2.1 gm. of cement[2]); then sand was added on the cement layer until the column totalled 12 cm. in height. Then a constant 6 cm. depth of tap water was placed on top of the sand.

In one experiment, on the seventh day following the establishment of approximately constant percolation, "poor" clay at 2 grams per liter of water was added to the water passing through the tube. This was done because under natural conditions the water entering canals and reservoirs always contains a certain amount of suspended particles which exert some kind of a warping effect.

Table 1 shows the results of these experiments.

In spite of the low binding value of the cement, the results of the preliminary experiments showed that the presence of an intervening layer of cement 1.5 mm. thick installed in the stratum of subsurface material with high permeability, considerably decreased percolation.

It was established that the impervious effect of the lining was noticeably raised when the cement was mixed 1:3 with sand, and also when sedimentary material was simultaneously used.

Second Series

The results of the preliminary experiments gave us a basis for continuing to work out this idea under better experimental conditions using a greater number of treatments. Primarily, we had to increase the size of the containers used as much as possible, since it seemed (this was confirmed by later experiments) that the absorption of water was intensified by the mutual adherence between cement and glass.

Jars 30 cm. high and 16.6 cm. in diameter, similar to those used in pot experiments, were prepared. Holes drilled in the bottoms of these cylindrical containers were large enough to provide unimpeded flow of the water percolating through the subsurface material being tested. This material presented a cross-sectional surface area of 216.42 cm.^{2}

Copper screens with openings 0.25 mm. in diameter and numerous supplementary holes 1 to 1.5 mm. in diameter were placed on the bottoms of the jars. A layer of gravel 2 cm. thick was placed on the screen; the sand being tested was added on the gravel to a height of 10 cm. from the bottom of the jar. The sand was saturated with water and became somewhat more compact. Cement, mixed with sand in various proportions, was added on the surface of the sand. In most cases the height of the calculated layer of pure cement did not exceed 1.5 mm. Again a 9 cm. depth of sand was added on powdery mixture of cement and sand, which appeared to be uniformly dry. The containers thus prepared were filled almost to the top with tap water. The result of this was a layer of water extending 10 cm. above the surface of the sand and 19 to 19.5 cm. above the sand-cement layer (Fig. 1). In some of the experiments when the water percolated very slowly, its level remained at the same height for several days.

In all these experiments the subsoil material under test was represented by sand known to have a high rate of percolation. It was made up of particles of the following separates: less than 0.005 mm. 0.2%, from 0.005 to 0.05 mm. 1.3%, from 0.05 to 0.25 mm. 25.4%, from 0.25 to 1 mm. 60.6%, from 1 to 3 mm. 12.5% (analysis by N. G. Inyushkin).

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[2] The cement used in the experiment was one of the portland types.

After the sand layer had been wet, the loaded cylinders were placed together on a wooden stand and the percolate was caught in bottles.

An examination of the results of the experiments performed with different kinds of cement at different sand-cement ratios: First, the results for *jar 9, the control,* in which the combined thickness of the sand and gravel was 20 cm. and the cement layer was omitted, showed

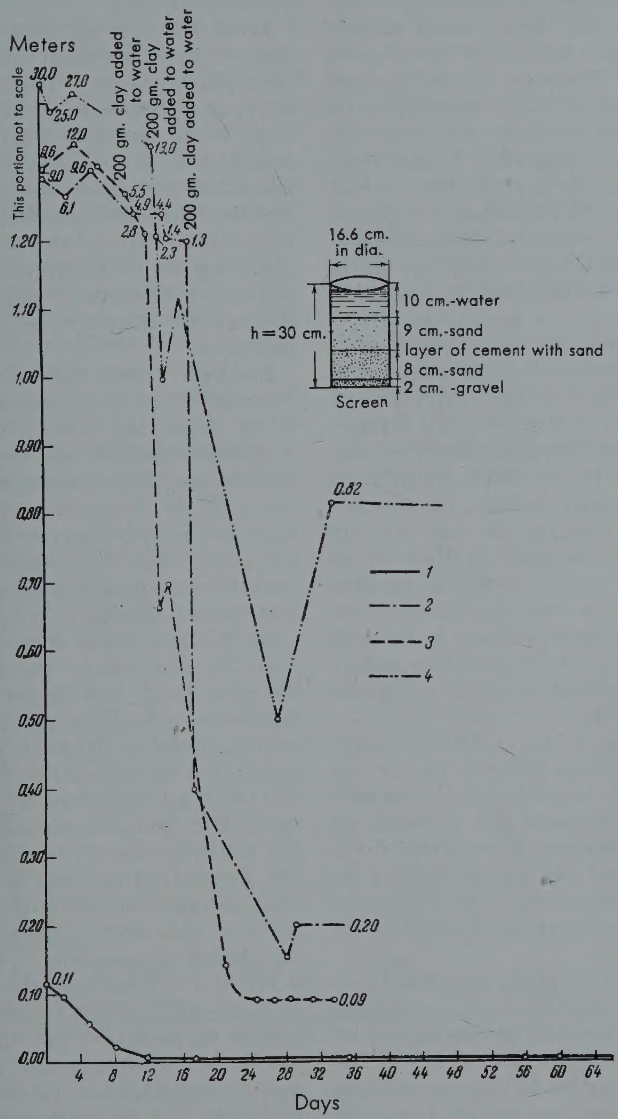

FIG. 1.—Water percolation rate in m. per day. 1—Jar 2A: hydrophobe cement 42.5 gm., sand 127.5 gm.; 2—jar 4: trass cement 39.9 gm., sand 120.0 gm.; 3—jar 3: quick-setting cement 42.5 gm., sand 128.0 gm. 4—control: sand alone.

that the initial percolation rate was 30 m. per (24 hour) day; on the 2nd and 5th days the rate began to decrease noticeably and on the 12th and 13th days the rate was constant at 13 m. per day.

At this point we used a suspension of 200 gm. of clay to determine the effectiveness of this method of decreasing the percolation in the sand. The clay contained 48% of particles less than 0.005 mm. in diameter; in this fraction the particles smaller than 0.001 mm. in diameter amounted to 32% of the clay. On the 33rd day, after the sand had subsided noticeably in the jar, the percolation rate was 0.82 m. per day, whereas in the preceding days it had varied from 0.5 to 1.0 m. per day (see Fig. 1). Such an abrupt change in the percolation rate was evidently caused by a change in the temperature, a factor not considered in carrying out the experiments. Thus, the result of clay suspension was a 15.8-fold decrease in percolation.

Jar 1. The impermeable layer was composed of brand 500 hydrophobic cement with sand in a 1:3 ratio (42.5 gm. to 127.5 gm.). The experiment was begun on March 6 (initial wetting). On March 7 the water level was filled to the top mark and did not fall on March 8 and 9. On April 20, that is, after 44 days, the percolate (and evaporation loss, for the jars were not carefully covered) amounted to 0.007 m.—an average daily rate of about 0.0002 m. On April 20 the height of the water column above the cement layer was increased to 0.5 m. by fastening a second jar on top of the first with asphalt. Several days of observation showed a complete absence of percolation.

At the beginning of May a rubber casing 2 m. long and the same diameter as the jar, was attached to it and the whole system was filled with water, first to a height of 1 m., which did not cause the appearance of any water at the outlet of the jar, and then to 2 m. Such a great increase in the pressure caused the glass jar to burst. A crack formed at the junction of the asphalt with the glass.

Jar 2A. On the basis of the extremely favorable results in causing a sharp decrease (practically a cessation) in the percolation, we repeated the experiment carried out in the first jar to obtain confirmation. In this case, evidently because we were less successful in adding the mixture uniformly on the surface of the sand, the percolation rate during the first several days of the experiment was somewhat higher than i the first jar (see Fig. 1). The initial rate of wate percolation in this experiment was 0.11 m. pe day; in 7 days it had dropped to 0.048 m. pe day. On the 14th day it was 0.0039 and finall by the 48th day the percolation rate had becom about the same as that in jar 1—approximatel 0.00036 m. per day.

Jar 2. The layer was made up of an unknow brand of Portland cement mixed 1:3 with san (48.7 gm. to 146 gm.). The impermeable valu of Portland cement proved to be extremely low Thus, in the first several days the percolation amounted to 15 m.; thereafter a decrease in percolation proceeded very slowly and on the 12th day the decrease was 7.6 m. per day. It was not until two 100 gm. batches of clay suspension had been added on the 15th day that the percolation rate went down to 0.9 m. per day, which was the value for the control after the addition of suspension.

Jar 3A. To check the impermeable value of Portland cement the experiment was repeated in jar 3A, but this time brand 500 cement was used. A repeated experiment also showed the very low effectiveness of this cement brand (in small quantities). In the disassembly of jars 2 and 3A it was noted that the concrete which had formed was quite porous (it was stained throughout almost the entire mass, and especially at the glass-concrete junction in jar 2, by an ink solution).

Jar 3. Quick-setting (spreading) cement was used. The sand cement ratio was 1:3 (42.7 to 128 gm.). For 7 days the percolation rate was high—about 9 to 12 m. per day. After the repeated addition of 100 gm. batches of clay suspension (on the 8th and 14th days) the percolation rate began to decrease fairly rapidly and on the 26th to 28th days stabilized at an average rate of 0.085 m. per day (see Fig. 1). Thus a 130 fold decrease in the percolation rate took place from the initial rate and the percolation rate was finally only one tenth of that of the control after the addition of suspension.

Jar 4. A 1:3 mixture of trass cement (39.9 gm.) and sand (120 gm.) was used. In the first six days the percolation rate was 6 to 9.6 m. per day but in the following days it decreased to a daily average of 4.5 m. On the 13th and 15th days single 100 gm. batches of clay suspension were added, which decreased the percolation rate on the 16th day to 0.4 m. per day. On the 27th and 28th days the percolation rate was established at 0.18 m. per day. Thus the effect of the trass cement was to decrease the percolation rate until, before adding suspension, it was about 3 times as small as the control rate and after adding suspension 4.5 times as small (see Fig. 1).

Jar 5A. The purpose of this experiment was to clarify the importance of the inert portion composition of the concrete layer component. In this case 128 gm. of loess-like clay loam replaced the sand; it was mixed with 40 gm. of brand 400 trass cement. In the first four days the initial percolation rate decreased from 6 to 2.2 m. per day and in one more day to 1.1 m. per day; for the remainder of the time, down to the 30th day, the percolation rate remained between 0.7 and 0.9 m. per day.

Jar 3B. In this experiment the same inert component was used—loess-like clay loam—while the cement used was that shown in other experiments to have such high impermeable properties, the hydrophobic brand 500 cement (42.5 gm.).

During the first two days the percolation rate decreased from 1 to 0.06 m. per day. In the following days the decrease in the percolation rate took place somewhat more slowly, so that until the end of the experiment (on the 31st day) the curve had the form of a broken line varying between 0.03 and 0.02 m. per day (Fig. 2.).

As seen from the experiments carried out in jars 5A and 3B, in which loess-like clay loam replaced the sand as the inert material, the imperviousness of the concrete material was lowered considerably, especially when compared with the capacity shown in jars 1 and 2A which used the same hydrophobic cement, but mixed with sand. In jar 2A on the 13th day the percolation rate was 0.002 m. per day while in jar 3B it was 0.022 m. per day. That is, the percolation rate was ten times as great in the second case.

It is obvious from the experiment results that the greatest impervious effect was shown by hydrophobic cement. For this reason, and also because it is cheap, this type of cement was studied in different applications in all the remainder of the experiments.

The following two experiments were formulated to determine the impermeable value of a mixture of two kinds of cement.

Jar 5. The mixture used here consisted of 12.2 gm. of hydrophobic cement and 16.3 gm. of Portland cement (the calculated weight of a 1 mm.

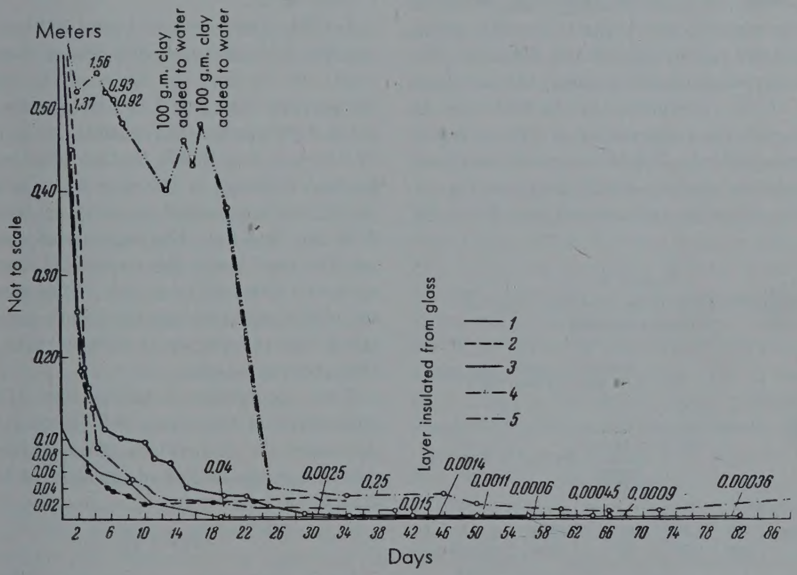

FIG. 2.—Water percolation rate in m. per day 1—Jar 2A: hydrophobic cement 42.5 gm., sand 127.5 gm.; 2—jar 3B: hydrophobic cement 42.5 gm., loess-like clay loam 127.5 gm.; 3—jar 6: hydrophobic cement 42.5 gm., sand 180 gm.; 4—jar 8: hydrophobic cement 21.3 gm., quick-setting cement 21.3 gm., sand 170.0 gm.; 5—jar 9A: hydrophobic cement 42.5 gm., sand 255.0 gm.

layer of each cement) with 122 gm. of sand (a 1:4 ratio). On the first day the percolation rate was 6.86 m. per day, on the 4th and 6th day the percolate decreased to 2.8 to 2.1 m. per day and on the 11th day to 1 m.; following the use of a single 100 gm. batch of clay suspension on the 13th and 15th days, the percolation rate decreased noticeably and settled at 0.018 m. per day on the 39th day of the experiment. Thus, even a very small amount of hydrophobic cement in an insignificant total amount of both cements produced a greater effect than when only pure portland cement was used. This is obvious when the results of this experiment and those of the experiment with jar 2 are compared.

Jar 8. The mixture used consisted of 21.3 gm. of hydrophobic cement and 21.3 gm. of quick-setting cement with 170 gm. of sand (a 1:4 ratio). On the first day the percolate amounted to 3.7 m. However, as early as the second day of the experiment there was a sharp decrease in the percolation rate. On the following days and down to the 14th day a gradual decrease in the percolation rate took place until it reached 0.4 m. per day. One hundred grams of fine clay loam was added with the water on the 15th day and another 100 gm. was added on the 16th day: following this, the percolation rate began to decrease again, reaching 0.012 m. per day on the 47th day. The percolation rate continued at about this rate until the end of the experiment on the 85th day. In this case, too, the replacement of 50% of quick-setting cement by hydrophobic cement decreased the percolation rate about eightfold (see Fig. 2).

The two following experiments, jars 6 and 9A, were formulated to find the best ratio of hydrophobic cement to sand. As seen in previous experiments using this type of cement, a 1:3 cement-sand ratio in the layer gave favorable results.

TABLE 2

Characteristics of the cements used in the experiments

Type of cement	Brand	Bulk density	Amount of cement, gm. in a layer 1.5 mm. thick		
			For surface area of sand in experiments (216.42 cm.²	Per m.²	Remarks
Hydrophobe	500	1.31	42.5	2000	
Portland	500	1.50	48.7	2250	Figures have been rounded off
Quick-drying (spreading)	500	1.35	42.7	2000	
Trass	400	1.23	39.9	1847	

It must be kept in mind that with such a rati the resulting concrete layer does not exceed 4 t 5 mm. It is understandable that the distributio of such a small quantity of material in a uniform layer over a large area can result in considerabl technical difficulties. For this reason any increas in the inert material (in this case, sand) in th concrete mixture would be desirable.

The results of these experiments:

Jar 6. Brand 500 hydrophobic cement, 42.5 gm., sand, 180 gm. (a 1:4 ratio). On the first day the percolation rate was 1 m. per day, but on the following day it decreased to 0.26 while on the 7th day it was 0.1 m. per day. In the following days the percolation rate curve fell very gradually and on the 27th day the rate was 0.008 m. per day; on the 59th day it was 0.0009 and on the 120th day it was 0.00048. The latter value was close to that obtained in jar 2A, in which the cement-sand ratio was 1:3. However, the percolation rate decreased considerably more slowly in jar 8 than in jar 2A and even less than in jar 1 (see Fig. 2).

Jar 9A. Here we used brand 500 hydrophobic cement, 42.5 gm. with 255 gm. of sand (a 1:6 ratio). In the first few hours of the experiment the seepage rate was 1 m., but in less than 24 hours it dropped to 0.45 m. and during the second 24 hours it was 0.187. In the following days a gradual decrease in the rate was observed and finally the rate settled at 0.015 m. between the 27th and 36th day. The experiment was stopped and the sand above the concrete layer was loosened and dried for a month. When the jar was again filled up to the top mark with water, percolation took place again at the same rate as before the sand was loosened.

Thus, an increase in the amount of the inert component of the concrete layer to a 1:6 ratio decreased the impervious effect of the hydrophobic cement 17-fold in the first 24 hours and 20-fold on the 24th day.

Third Series

From the foregoing results we concluded that the highest imperviousness was shown by hydrophobic cement used in very small quantities by weight and mixed 1:3 and 1:4 with sand.

The high effectiveness established by the experiments in jars, in which the hydraulic head on the concrete layer was only 20 cm. (with two exceptions, one 50 cm. and the other 1 m.), naturally provokes the question: what would be the impervious effect of concrete layers if they were to be subjected to a hydraulic head of 1.5 to 2 m. or more, that is, of the water depth which is usual for large canals and reservoirs?

The best method of resolving this question would be to set up appropriate experiments in a pond or canal located in permeable subsoil. This was not possible. However, the following experiment was completed. Two asbestos-cement pipes, 1.95 m. high and 14.5 cm. in diameter (with a cross-sectional area of 165.13 cm.) were packed in the same way as in the second series of experiments except that a thicker layer of sand (about 40 cm.) was added on the concrete layer. Initially, one of the tubes served as a control, that is, it was filled with the sand being tested to the same height as in the experimental tube, but without the concrete layer. After a constant percolation rate had been established the tube was refilled, but this time a concrete layer was installed. Thus, the maximum head of water was 1.5 m. on the surface of the sand and 1.85 m. on the cement layer.

The subsurface material tested consisted of sea sand and selected rounded stones and coarse gravel.

A percolation rate of 6.6 m. per day was established in the control tube on the 10th to the 15th days. Onto the metal screen in tube A were placed first a layer of 2 to 3 cm. of gravel and then 6 to 7 cm. of sand; following this 32.5 gm. of hydrophobic cement (calculated as a layer of pure cement 1.5 cm. thick) mixed with 97.5 gm. of sand was added. Another layer of 38 to 40 cm. of sand was added on the layer. After the tube had been set in place it was filled to the 23 cm. level with tap water; this was raised to the 63.5 cm. level over a period of eight days. After a sharp decrease in the percolation rate (to 0.003 m. per day), the water level in the tube was raised to its maximum height, resulting at first in a fairly large increase in the percolation rate—to 0.023 m. per day. However, in the following days the percolation rate began to drop again and on the 17th to the 22nd days it was 0.014 m. per day.

In the other tube, B, from which the control filling had been removed, the concrete layer was calculated to correspond to a layer of pure cement 2 mm. thick and included sand at a 1:4 ratio by weight, which corresponded to 42.5 gm. of cement and 168 gm. of sand. For the first six days the water head was maintained at 0.5 m. over the sand. The percolation rate decreased from 0.07 to 0.01 m. per day. After the water head had been raised to the maximum, the percolation increased sharply and reached almost 0.09 m. per day. Thereafter, the percolation rate began to fall gradually and on the 22nd day it reached a constant rate of 0.01 m. per day. On the 48th day 80 gm. of clay suspension was added, after which the percolation rate began to fall again and on the 66th day it was 0.005 m. per day.

It must be noted that the experiments set up in asbestos-cement tubes should not be considered as reflecting precisely the actual percolation rate through a cement-sand lining, since the joint between the concrete and the walls of the tubes was not tight enough. It is possible that the percolation rate was somewhat higher in the last series of experiments than in the first series, which used wide glass jars, because of the technical difficulty involved in the uniform spreading of the mixture over the surface of the sand in the relatively narrow tubes, and also because of the subsidence of the sand and the concrete layer after maximum filling of the tube with water. The percolation rate was evidently also increased by an increase in the height of the water column above the concrete layer.

In spite of a certain crudeness the experimental results showed the high imperviousness of the mixture of hydrophobic cement and sand. Thus, where the percolation rate of the control was found to be 6.6 m. per day, a layer with a quantity of cement calculated to have a thickness of 1.5 mm. decreased the percolation rate 660-fold. When the layer contained cement calculated to be 2 mm. thick, the percolation rate without clay suspension was smaller than that of the control by a factor of 660. After a small amount of clay was added to water the percolation in the experimental tube was smaller than that of the control by a factor of 1650.

The results of these experiments were communicated to specialists in the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, the Main Administration of Water Resources, Ministry of Agriculture, USSR and the Republic State Institute for Design and Planning of Water Resources and Reclamation Development. Engineer M. A. Bul'gin suggested that after the canals or reservoirs had been drained the concrete layer might be subjected to deformation and cracking under the action of freezing. This would, to a considerable degree, be manifested in seepage increase. Because of this pertinent suggestion, in the late fall before the onset of freezing weather, we drained the water from the tubes used in the third series of experiments, but left the sand in them saturated with water. During the winter of 1956 to 1957 the experimental apparatus froze and thawed a number of times in accordance with the weather conditions. On April 30, 1957, when lasting warm weather began, the tubes were filled to the top with water.

Observation showed that in the first several days the percolation rate had become somewhat higher than in the last days of the experiments in the fall of 1956; from May 4 to 6 it was 0.019 m. per day in tube A and 0.01 m. per day in tube B from May 28 to July 31.

Thus, in our experimental setup, freezing had practically no effect on the percolation rate of the concrete layer containing hydrophobic cement.

Conclusions

1. Experiments made on the installation of artificial layers at shallow depths analogous to the illuvial strata of natural soils showed that under certain conditions the imperviousness of such layers can be very high.

2. Four different types of cement were tested as the bonding agent for the layer: hydrophobe, Portland, trass and quick-setting. Hydrophobe reduced percolation most sharply.

3. The best inert ingredient for the concrete mixture was sand used at a cement-sand ratio of 1:3 or 1:4. When loess-like clay loam was used as the inert ingredient the impervious effectiveness of the concrete was lowered considerably.

4. The simultaneous use with layers of a small amount of sedimentary material in the water raises the imperviousness of the layer. Since water reaching canals and reservoirs from natural sources always contains a certain amount of solids in suspension, the impervious action of concrete linings will become intensified.

5. By the use of the experimentally-determined optimal kind of cement at its optimal ratio to sand, it was demonstrated that at small heads of water (up to 1 m.) the calculated equivalent of a 1.5 mm. layer of cement (2 kg. per m.^{2} of soil) decreased the percolation of water from 13 m. pe day to between 0.00036 and 0.0009 m. per day that is, by a factor of more than 20,000. This decrease was more than 1200 times as great as th decrease caused by the addition of clay suspension to the control. At a 1.9 m. head of water on a concrete layer using the same quantity of cement the percolation rate decreased from 6.6 m. pe day to 0.01 m. per day, that is, it decreased by a factor of 660; and when there was a 25% increase in the cement and clay suspension was also used the factor was more than 1600.

6. When testing different cements and mixtures of them with sand, the water must be maintained in a layer no higher than 15 to 20 cm. above the level of the soil material for seven to ten days. The water should not be raised to the projected level until after the cement has set.

7. The protective layer of soil material added on the concrete mixture to protect it from mechanical damage should be no thinner than 15 to 20 cm. An increase in the thickness of this cover layer, like an increase in its clay content, increases its imperviousness.

8. Freezing and subsequent thawing of a concrete layer made from hydrophobic cement did not change its imperviousness.

9. The proposed method of decreasing the percolation of water in inherently highly permeable subsoils by constructing a shallow hydrophobic cement-sand concrete layer was highly effective at a small outlay of cement.

The results of these experiments are not adequate to resolve the technical questions involved in the wide use of the suggested method for controlling seepage. To clarify questions not adequately covered by the work described here the following tasks must be carried out:

a. Development of a technique for large-scale work making maximum use of machinery.

b. Determination of the optimum amount of cement for lining at different heads of water in canals and reservoirs which are more than two meters deep.

c. Determination of the economy of the proposed method in comparison with other methods of controlling seepage.

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THE CONTRIBUTION OF SOVIET SOIL SCIENCE TO THE STUDY OF BULGARIAN SOILS

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THE article by I. V. Tyurin on the development of soil science in the USSR during the past 40 years (24) is of exceptionally great interest for Bulgarian soil scientists and agronomists. But one important element mentioned only briefly in the article should be emphasized. This is the contribution of Soviet soil scientists to the soil science development of certain neighboring countries. In that connection, this article will mention reasons why Bulgarian soil science is indebted to Soviet soil scientists.

In 1908 K. D. Glinka included a world soil map in his soil science textbook (12). Arbitrarily—without any previous research—this map classified the soils of all Southern Bulgaria as terra rossa, while the soils of the Central and Balkan Mountain districts were designated as "mountain" or endodynamorphic, that is, soils on which the parent rock has had a more significant effect than have external conditions. They include soils with particles predominantly larger than 3 millimeter in diameter, as well as those having particles smaller than 3 millimeter and include rendzinas, for example. In Glinka's opinion a large part of Northern Bulgaria is occupied by podzolic soils with areas of chernozems. However, as explained later, there are no terra rossa or podzolic soils in Bulgaria. The mountain soils are shown on the Glinka map without further subdivisions; and the map shows the Northern Bulgarian chernozems without sufficient accuracy.

In 1911 the Bulgarian Ministry of Agriculture set up an Agricultural Experiment Station at Sofia with a soil or, as it was called, "agrogeological" division headed by the geologist N. Pushkarov. Among the tasks of the station was the detailed study of the country's soils. In 1913, Pushkarov, who was considered the founder of Bulgarian soil science, published a "Soil-Geological Sketch of the Sofia Valley" (18). However, of the soils delineated there: soddy, chernozems, krasnozems (terra rossa), half-bog, humic-carbonate, flood-plain and alluvial, only the humic-carbonate soils had been correctly classified. Later Pushkarov described the soils of the Botevgrad, Blagoyevgrad and Pirdop districts, and also investigated the soils of some individual points o the country. He adopted V. V. Dokuchayev's genetic classification of soils but only in a forma way, since most of the soils which Pushkarov mentioned were not indigenous to Bulgaria or had not been designated accurately. This is also true of Pushkarov's soil map of Bulgaria, published in 1931 at a scale of 1:500,000 (17), in which the following soils were distinguished: chestnut, dark chestnut, chocolate chernozem, podzolic, podzolic forest, intermediate podzolic, chernozem-like clay (which he had previously called chernozem), skeletal podzolic mountain soils, immature soils of river and lake alluvium, and so forth.

Certain of these soil groups, for example the chestnut and the chocolate chernozem, are quite unusual for the moist climatic conditions found in Bulgaria.

In 1927 G. Bonchev, professor of petrography and mineralogy at the University of Sofia, published an article (26, p. 281) on Bulgarian soils which was accompanied by a map showing, for the first time for Bulgaria, brown forest soils, as well as chernozems (without sub-types, and with incorrect borders) and small areas of chernozems in Southern Bulgaria where they have not developed. The chestnut soils are also mentioned incorrectly, and the author has introduced concepts, which he has not defined, of "lime soils" and "high-mountain soils" as independent soil groups.

In 1930 a study of Bulgarian soils was made by V. Holstein, assistant to Professor Stremme of Danzig, whose soil map appears in the publication "Agriculture in Bulgaria" by S. Botev and I. Kovachev (4). This map shows the following kinds of soils fairly vaguely: fine chernozem, low in humus but containing 4 to 7% of it along the course of the Danube; "decomposed" (probably leached) chernozem; brown forest soil (in both Northern and Southern Bulgaria; leached forest; humic-carbonate; immature mountain; lacustrine deposits (a unique definition of smolnitsy); the immature soil of clay-humic deposits (probably also smolnitsy); and bog soils.

In 1937 Stremme published a map of Europe

(28), using data for Bulgaria taken chiefly from Pushkarov's map and changed only negligibly. For example, the smolnitsy which Puskarov called "chernozem-like" Stremme designated as degraded forest-steppe chernozem, an arbitrary and inconclusive definition. I will not list the remaining soil maps of the country or parts of it published until 1948 since this is given in one of my papers (21).

Soil science in Bulgaria took on a more definite and correct direction in 1921 with the founding of the School of Agronomy of the University of Sofia. In 1926 Stranski published the first soil Science textbook in Bulgarian; new editions were published in 1935 and 1946 (22). A. A. Yarilov wrote a favorable review of the second edition of this text (25) which is written in conformity with Dokuchayevian doctrine and has been the principal textbook of all graduating agronomists and foresters for almost the last 30 years. During this period Bulgarian soil science has developed exclusively on the basis of the Russian Dokuchayevian doctrine, to which Bulgarian soil science is related in the most intimate fashion.

From 1921 to 1947 a number of soil science papers were published which dealt with the origin of certain specific Bulgarian soils assigned to the smolnitsy group; they were considered to be brown forest and saline soils. A series of regional soil investigations were carried out as well as research on texture, moisture capacity, structure and fertilizer requirements. The list of soil science papers published in Bulgaria up to 1947 contains 110 references (5).

However, the individuals dealing with soil science both in the School of Agronomy and the Ministry of Agriculture were unable to give correct definitions of Bulgarian soils. The cause of this lay in the unique nature of the natural conditions of the country. The chernozems are characterized by a small amount of humus, not always by their typical black color, the absence of a stratum of gypsum under the illuvial-carbonate horizon, general compaction of the horizons, and by micellar phenomena. Here, there are no biocoenoses which include stipa. All these facts interfered with the correct orientation of soil scientists whose guidance consisted of the general references in the literature. Certain climatic factors were not considered, for example, the lack of a clearly manifested winter, discontinuous snow cover, alternating periods of considerable precipitation and droughts, making possible the occurrence of micellar phenomena, the moister climate in which Bulgarian chernozems generally develop, the weak development of stipa which is replaced by widespread phytocoenoses of bluestem (*Andropogonetum*). Nor was consideration given to the exhaustion of the chernozems because of their use for two thousand years, which would cause a decrease in their humus content and a change in their color acquiring a brownish tinge. As a result of these same difficulties Romanian soil scientists designated similar soils in Rumania as chestnut and those adjoining them as southern or chocolate chernozems. This terminology was also adopted by a number of Bulgarian investigators.

The gray forest soils of Bulgaria are also unique. Their illuvial horizon is strongly developed and there is considerable compaction as a result of clay enrichment, but a definite podzolized horizon is lacking. The podzolic aspect is manifested in the deposition of powdery particles along the structural elements. A brownish tinge is very frequently predominant in their color. It is these specific characteristics which prevented the detection of this kind of soil in Bulgaria. Here, where two kinds of climates inter-mingle—the Mediterranean, developing to a certain extent in Southern Bulgaria, and the Central European, occurring in Northern Bulgaria—unusual conditions for soil formation occur. The presence of hydrated iron oxides in all the soils—in chernozem, gray forest soils and especially in the Southern Bulgarian soils—gives the soils light or dark brown. This has caused difficulties for Bulgarian soil scientists in making correct determinations and has caused a disproportionately broad distribution of the designation of brown forest soils. The specific kind of soil called "smolnitsa," first described by I. A. Stebut for Yugoslavia (20), was firmly established by Stranski for Bulgaria in 1933 (27). Before the work of the Soviet-Bulgarian soil expedition it was believed that podzolic soils were developing under the mountain coniferous forests.

Scientific activity in soil science during the period ending in 1947 was of an unorganized nature and was determined by the interests of individual scientists in the School of Agronomy (where they studied chiefly soil science questions) and by the necessity of carrying on scientific work at their own expense. They were provided only with laboratory investigators, access to the literature and facilities for publication of their papers. The funds for the investigation of soils were allotted only to the Agricultural Experiment Station in Sofia, which was later renamed the Central Agricultural Experimental Institute of the Ministry of Agriculture.

From the beginning of the socialist reconstruction of Bulgaria in 1944 there arose a need for the renovation of agriculture, increasing crops, and broadening land-improvement measures, especially irrigation. Conditions in Bulgaria allowed the large-scale use of water for this purpose. In 1944, 35,700 hectares were irrigated; in 1948, 88,300; in 1952, about 240,000 and in 1957, more than 400,000. In order to assure irrigation leading to a true increase in crops and to avoid such of its harmful consequences as water-logging and salinization and also for the most nearly correct use of the water in irrigation, research had to be done on the soils to be irrigated.

With the organization in Bulgaria of agricultural labor cooperatives, the need arose for the correct soil identification and for mapping them. In 1947 the Ministry of Agriculture turned to the government of the USSR with a request for cooperation in soil research in Bulgaria. The Soviet soil scientists I. P. Gerasimov and I. N. Antipov-Karatayev arrived in Bulgaria in July, 1947. A Soviet-Bulgarian soil expedition was organized which travelled almost 5,000 kilometers through Bulgaria. The expedition brought together soil scientists from the Soil Institute of the Bulgarian Academy of Sciences and from the Ministry of Agriculture and the School of Agronomy of the University.

As a result of Antipov-Karatayev's and Gerasimov's knowledge of Bulgarian soils, the presence here was established of the completely new cinnamon-brown soils which were previously unknown to Bulgarian soil scientists and which had been first described by S. A. Zakharov. In Bulgaria this soil contains less humus and is distinguished by a considerable enrichment in clay and by compaction not only of the deeper horizons but also of the humic stratum, which is thicker. An interesting aspect is the development of podzolization processes in this soil, leading to the sub-group of podzolized cinnamon-brown soils.

Soviet soil scientists established that podzolic soils are not encountered in Bulgaria, even in mountain districts where, because of climatic reasons, brown forest soils develop under the forests. Only the initial stages of podzolization were established in other soils groups—gray forest, brown forest, cinnamon-brown and chernozems. In Bulgaria chernozem soils develop under more moist conditions than in the USSR. They are leached free of salts and there are no sulfates even in the parent material. Because of the uneven distribution of precipitation during the year and the alternate abundant rains with periods of drought, favorable conditions exist for the formation of the carbonate pseudomicelles which are especially characteristic of the carbonate subgroup of chernozems. An influence is also exerted by the bluestem biocoenosis under which chernozems usually develop in Bulgaria. A considerable part of these chernozems (the leached and the podzolized) were formed under the conditions of forest-steppe with oak forests which had, for the most part, been destroyed long ago. This does not apply to the carbonate and typical chernozems. Antipov-Karatayev and Gerasimov explain the low humus content and the chestnut or brown tinge of the plow layer of chernozems by the overplowing which has resulted from centuries of tillage and agricultural use and which is reflected in the nitrogen content. Bulgarian chernozems, especially the leached ones, have thicker, denser horizons containing more clay.

The smolnitsa soil group was recognized as independent although it has been designated "chernozem-smolnitsa," a term with which it is difficult for us to agree in view of the lack of convincing proof of the similarity of smolnitsa soils to chernozems. Such a designation led to the incorrect interpretation of this soil group by other authors using this classification. For example, D. G. Vilenskiy mentions that in Bulgaria the chernozems are represented by a "unique family of chernozem-smolnitsy" (8, p. 431). E. B. Valev also misunderstands the taxonomic position of smolnitsy. In his book "Bulgaria" (6) the statement is made that smolnitsa is a special "variety of chernozem" regardless of the fact that these soils are differentiated as groups, not as series. In the new edition of this book (7, p. 63) a correction has been inserted reading "a special chernozem group called chernozem-smolnitsy in Bulgaria." A. S. Radov (19, p. 112) writes that smolnitsa "is a typical chernozem." To avoid misunderstandings we need to re-establish the designation of the specific soil group, smolnitsa, given by Stebut. In considering the position of these soils in general soil classification, V. R. Volobuyev (9) correctly designated them smolnitsy, and not chernozem-smolnitsy. In the classification by Antipov-Karatayev and Gerasimov, proof is given of the relation between the smolnitsa soil group and the cinnamon-brown soils which developed under the influence of the Mediterranean sea. However, there exist considerable small areas of smolnitsy in Northern Bulgaria which have developed under completely different circumstances from the cinnamon-brown soils, in any case outside the Mediterranean influence.

Soviet soil scientists have clarified the picture of the soil groups, sub-groups and varieties in Bulgaria and have resolved the doubts of Bulgarian soil scientists. They have compiled a 1:1,000,000 soil map of Bulgaria on the basis of modern views which have been accepted by soil science. In 1948, Antipov-Karatayev and Gerasimov (3) published a sketch of the Bulgarian soil groups with a short characterization now serving as the basis for further activities by Bulgarian soil scientists. Thus, there now exists in Bulgaria a clear and correct classification of the groups and kinds. Regular patterns of their geographic distribution and origin have been established. On the basis of this we have worked out and completed in 1957 a 1:200,000 soil map of the country and also a more accurate and detailed map of the Thracian lowland and Southern Bulgaria at a scale of 1:50,000. The former was compiled by Ye. Tanov (23), the latter by V. Koynov (16).

Soviet scientists have not limited their work in Bulgaria to expeditions and general instructions. They have taken many samples for investigation, they have visited our country often after investigations and it was their idea to publish a special joint monograph on Bulgarian soils (the work was divided between them and Bulgarian soil scientists, Soil Institute, Ministry of Agriculture). The monograph has been written. It is to be published simultaneously in Russian and Bulgarian, and in Bulgaria it is awaited with great interest. Independently of this, Gerasimov organized another expedition in 1954 when he toured Southern Bulgaria with Bulgarian soil scientists. He confirmed the existence of the meadow chernozem, originally discovered by V. Koynov, in Southern Bulgaria not far from Plovdiv, while in the Strandzh Mountains he established the presence of another soil group new to Bulgaria—a zheltozem in forests of oriental beech (*Fagus orientalis*). Antipov-Karatayev visited Bulgaria in 1955 and gained an intimate knowledge of the saline soils of the village of Belozem, Plovdiv district and gave general instructions on desalinization which are now being worked out. Some papers have been published in connection with the Soviet-Bulgarian expedition (2, 3, 10, 11).

At the invitation of the Bulgarian Forestry Administration, S. V. Zonn visited our country in the fall of 1955. He met with forestry specialists, toured the districts of the Rhodope Mountains, Rila, Vitosha, Pirin and, in part, the Balkan Mountains, and he visited the Dobrudzha. His impressions were presented in a preliminary article in the Bulletin of the Forest Institute, Bulgarian Academy of Sciences, for 1957.

At the invitation of the Bulgarian Academy of Sciences Zonn visited Bulgaria again in 1956 in connection with problems of water and forest resources. He organized a scientific research expedition into some Bulgarian forests, devoting special attention to two tree farms in the Rhodope Mountains and one in the Balkan Mountains. Representatives from a number of institutions took part in the expedition.

Zonn's book (15), which resulted from his visits and the observations he made in Bulgaria, was published by the Academy of Sciences of the USSR. He emphasized that for the correct organization of a tree farm as related to the general economic requirements of the country it is necessary to know the soils under the tree plantations and soil genesis and properties because these are intimately related to the growth and development of the forests. For this reason he recommends the study of the dynamics of soil processes in different soil groups in order to become acquainted with the nature and properties of forest soils and their evolution and to make possible an increase in forest productivity.

Aside from this, Zonn published two of his articles (13, 14) in 1956 in the Bulletin of the Soil Institute, Bulgarian Academy of Sciences. In addition, he forwarded for publication in volume 5 of the Institute's Bulletin an article entitled "Soils Under Spruce Plantations in Bulgaria." These soils have been little studied and are distinguished by quite specific characteristics.

We cannot fail to mention the working methods of the Soviet soil scientists who cooperated so fully with Bulgarian soil science. Many great investigators, chiefly from the western countries, have visited Bulgaria in the past, both before our liberation from Turkish domination and thereafter. The each usually worked quite independently and their work did not become known until after publication. On the other hand, during the Soviet-Bulgarian expedition, during trips and in the study of soils and their profiles in the field, the Soviet soil scientists I. P. Gerasimov and I. N. Antipov-Karatayev made detailed statements of their observations, gave exhaustive explanations and discussed all their considerations with the Bulgarian soil scientists taking part in the expedition. They transformed the expedition into a school bringing invaluable benefits. This was significantly reflected in the subsequent work of the Bulgarian soil scientists.

S. V. Zonn worked in the same way. He included as the co-authors of his paper on the soils under spruce plantations three scientific colleagues from among the Bulgarian specialists who accompanied him during the investigations of soils under Bulgarian forests. Thus, the collective method of scientific work was practiced in this case.

In conclusion, it must be emphasized that the help given to Bulgarian soil science by Soviet soil scientists during the last ten years has been exceptionally valuable, since because of their great experience and broad knowledge of the soils of the vast expanses of the Soviet Union and other countries, Soviet scientists have provided a correct and exhaustive characterization of the unique soils of Bulgaria.

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SOME QUESTIONS OF THE ENERGETICS OF SOIL FORMATION

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The study of the cycle of matter and of the exchange of matter among the lithosphere, hydrosphere and atmosphere and between them and organisms has been the subject of many papers. But the energetics of these processes, that is, the phenomena of the exchange of energy, has been the subject of far less research. At the same time, knowledge of the energetics of processes occurring in the geographical medium are very important (6, 7) to understand more precisely the nature of the interaction and correlation between individual components of the geographical medium. This statement is equally valid for the theory of soil formation.

The concept of soil formation as a complex process of the exchange of matter and energy between lithosphere, atmosphere and living matter has long been known and is now one of the basic concepts of genetic soil science. In particular, this idea has given rise to the concept of the great geological and the small biological cycles and their role in soil formation (3). But we are completely justified in speaking of the lack of necessary quantitative indices for the energetics of soil formation. We are now only at the very first stage, when clarification of very basic ideas can be expected. For this reason any discussion in the field of soil formation energetics at present, can be only an approximate, sketchy outline. But even under such circumstances the discussion can be of interest. The practical possibility of attacking an investigation of soil formation energetics has been stimulated in recent years by the appearance of data on the energetics of individual processes and phenomena which may be adapted to these purposes. In the present investigation the author uses a hydrothermal system which he proposed (4).

First we must make clear the basic components of the balance of energy of soil formation—primarily those components of the balance of energy directly related to the soil formation process. These are, so to speak, "working components" in soil formation.

The biological components are the most important group of phenomena of soil formation. V. R. Vil'yams' idea that soil formation is the process of the synthesis and destruction of organic matter is well known. A large part of the sun's radiant energy is accumulated in the humus. At present, the conversion of minerals is also considered, in many cases, to occur with the participation of a biological factor which may act both directly and as products of vital organism activities. A part of the energy of biological processes is expended in the form of heat.

Biological processes in the soil are closely related to evaporation and transpiration which, according to existing data, absorb a large portion of the sun's radiation. A definite portion of the thermal energy is expended on weathering processes (physical and chemical weathering). The sun's thermal energy affects the migration of water, which, in turn, transfers the soluble and dispersed portions of the soil along the profile or redistributes them according to the elements of the relief.

The energy balance of soil formation may be represented in general form by

$$Q = w_1 + w_2b_1 + b_2 + e_1 + e_2 + g + v \cdots \qquad (1)$$

in which $Q =$ the amount of energy taking part in soil formation; $w_1 =$ the energy expended in the physical decomposition of the soil-forming rock; $w_2 =$ the energy of mineral decomposition of the soil-forming rock in the weathering process; $b_1 =$ the energy accumulating in the humic substances; $b_2 =$ the energy expended in the biological conversion of organic and mineral matter (partially expended in the form of heat); $e_1 =$ the energy expended on water evaporation from the soil surface and from plants; $e_2 =$ the energy expended on transpiration; $g =$ the loss of energy from the mechanical migration of salts and of fine soil particles; and $v =$ the energy expended in the exchange of heat in the soil-atmosphere system (the annual balance, in most cases, is close to zero but in rare cases amounts to a noticeable amount).

Further, we expect to clarify the possible measurements of the basic components of the energy expenditure and of the regular patterns of changes in them as related to the principal zonal differences in the course of soil formation. The attempt to make such a calculation is only a first approximation to the solution of this problem.

Let us first consider the energy-loss processes of soil formation which are thought to be the most substantial in size; evaporation and transpiration. The data are too scanty to characterize these values separately as broad geographical differences, but it is possible to estimate the total evaporation, that is, the evaporation from the surface of the soil and plants, and the transpiration.

An estimate of the magnitude of the total evaporation with broad climatic differences is achieved fairly simply and with adequate accuracy on the basis of the hydrological interrelationships which have been demonstrated. The amount of total evaporation changes by a quite regular pattern according to a hydrothermal graph between limits of 50 mm. per year and less on the tundra and deserts and more than 1,100 mm. per year for moist tropical conditions.

The graph of the changes in total evaporation in relation to t and R and P (precipitation) was easily converted to a graph of the expenditure of heat on total evaporation (Fig. 1). This showed that on the tundra and deserts the heat expenditure on total evaporation amounts to less than 3000 to 6000 cal. per cm.^{2} per year. The uniquely low amount of heat expended on total evaporation in the tundra and hot deserts is naturally due to various causes. In the tundra it is related to the limited amount of heat received, while on the deserts it is related to the small actual quantity of moisture precipitated, the amount of which determines the amount of evaporation possible. The highest values for heat expenditure on total evaporation were reached under moist tropical conditions—more than 60,000 cal. per cm.^{2} per year.

It is a more complex problem to determine the energy expended on the biological processes of soil formation, that is, on the accumulation of energy in humus and on the intermediate reactions by which organic and mineral substances are formed. In this case it is better from the very beginning to avoid attempts to represent these expenditures analytically, according to individual kinds of biological activity in the soil, since in this field not even conflicting data exist. Only a few of the elements in the field of plant bioenergetics have been clarified (2, 15, 10, 13, 16 and others).

There are no direct determinations at all of the total expenditures of energy on biological soil processes. The remaining possibility is to determine these expenditures indirectly.

The total expenditure of energy on biological soil processes may be determined if consideration is given to the annual accumulation of plant material. The overwhelming part of the biological soil processes in any form are related to the decomposition of plant matter and to all possible transformations of it in the soil. Naturally, the general parameters of the energetics of these processes will be influenced by the amount of solar energy accumulating in the annual growth of the plant material. In the attempt to calculate the magnitude of the annual plant material growth we are hindered by a dearth of data from actual determinations of plant material growth under various ecological conditions. This is especially true of data from simultaneous determinations of the top and root growth.

To judge the amount of the annual growth of the above-ground plant material we used data

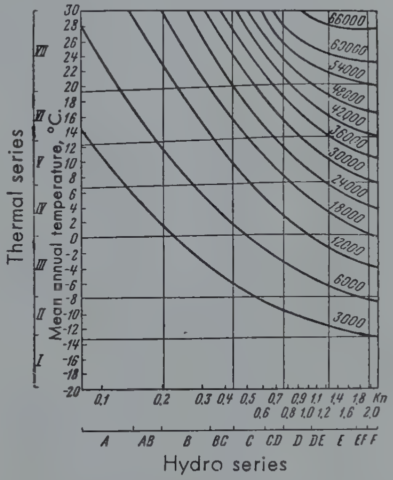

FIG. 1.—Energy expended on total evaporation, cal. per cm.^{2} per year. The moisture index on the abscissa of the hydrothermal system is found from the function

$$Kn = \frac{\text{total annual precipitation}}{\text{natural rate of evaporation (En)}}.$$

from Jenny (8), Kittredge (9), Rosanov (14), Lavrenko et al. (11, 12) and others (a total of 46 determinations), covering individual types of vegetation from the tundra, temperate-zone forests, tropical forests, steppes, semideserts, and so forth. When interpreted on the hydrothermal graph according to the climatic conditions of their location, these relatively few data enable us to develop a general order of changes in the magnitude of the annual growth of plant material in relation to climate.

The annual top growth becomes regularly larger in two basic directions: from the desert through steppe and savanna to the forest and, under very moist conditions, from the tundra through temperate-zone forests to the tropical rain forests. In these two basic directions the annual growth of plant material changes from minimal values of the order of less than 1 centner per hectare to more than 500 centners per hectare in tropical rain forests. In temperate-zone forests and on steppes and savannas the amount of plant material produced annually is from 20 to 100 centners per hectare.

The data on the annual growth of root material is so scanty that it is impossible to use them directly for making any kind of reliable judgment on the regular pattern of changes related to hydrothermal conditions. Of this parameter of the vegetation productivity it is known only that the ratio of the quantity of the top material to that of the roots varies greatly, chiefly in relation to zonal differences: the increase in root material volume in arid regions considerably exceeds that of the top material. Under very moist conditions this ratio is reversed.

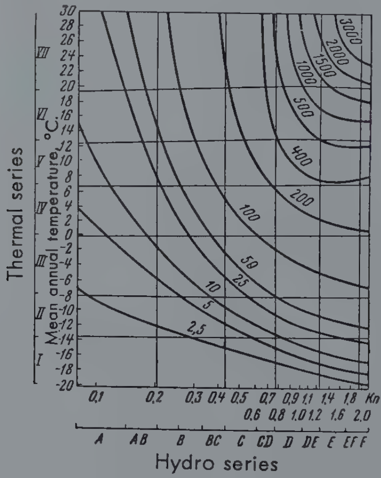

FIG. 2.—Energy reserves accumulated in the annual growth of plant material (tops and roots) in cal. per cm.^{2} per year.

For this purpose it is accepted conjecturally that under desert conditions the increase in the root material exceeds that of top material by a factor of 4, under semidesert conditions by a factor of 2 and under arid steppe conditions by a factor of 1.5: under steppe, forest-steppe and savanna conditions they are equal; and under forest and tundra conditions the increase in root material is only half that of the top material. The result of these conversions shows a quite regular pattern.

After the amount of annual plant material growth has been determined, we must calculate the amount of energy accumulated in this material. We will base this calculation on the following well-known equation for photosynthesis:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} \cdot C_6H_{12}O_6 + 6O_2 - 674 \text{ kcal.}$$

This equation shows that 3.75 kcal. of solar energy

$$\left(\frac{674 \text{ kcal.}}{180 \text{ g/mole } C_6H_{12}O_6}\right)$$

is expended on the formation of 1 g. of the product of photosynthesis. With this value at our disposal it is easy to convert to the energy expenditure taking part in the work of accumulating organic matter under different hydrothermal conditions. As seen from Figure 2, the expenditures of energy on the annual plant material production vary from between 2.5 to 25 cal. per cm.^{2} per year on the tundra and in temperate-zone deserts to 2000 cal. per cm.^{2} per year in tropical rain forests. Under conditions characteristic for the soils of temperate-zone forests and of steppes and savanna, these expenditures vary from about 100 to 400 cal. per cm.^{2} per year.

Let us go on to a clarification of energy expenditure in the weathering processes. Data on direct measurements of the energy expenditures in this field are, in general, lacking. There are only attempts to give a relative estimate of the weathering rate as related to hydrothermal conditions (17, 18, 8 and others).

At present it is possible to undertake the determination of the measurements of energy expenditures on weathering. We may consider as a premise for this the ideas of Belov and Lebedev (1) on the geochemical accumulators of energy, and also the latest results of soil-climatic investigations which throw light on the time rate of component moisture accumulation. At the exposed surface, in the zone of hypergenesis, a process of weathering develops accompanied by fractional crystallization of rock down to the colloidal state and by chemical conversion to the final form of oxides, hydrated oxides and free salts. This sweeping conversion of earth material is impossible without the expenditure of a considerable amount of energy. As a result, the products of the hypergenic conversion contain a high accumulated energy concentration.

According to Belov and Lebedev, there are a number of important facts and considerations which enable us to assume that in the inorganic cycle the geochemical accumulation of energy in the weathering zone takes place with the support of the radiant energy of the sun, this being the only powerful source of energy reaching the exposed surface. But the importance of the geochemical accumulation of solar energy does not consist only in its role as the moving force in the weathering process. The products of hypergenesis, being transformed into petroleum during the course of geological phenomena, "liberate" the free energy within them and become sources of endogenous power.

Belov and Lebedev's conception of the geological role of the sun's energy in a number of different relationships is hypothetical and it explains certain phenomena only sketchily, but fundamentally it is highly probable.

Rather than discussing each of Belov and Lebedev's ideas, let us take up some details of the energetics of certain of the typical weathering process reactions. Thus, the reaction of the complete decomposition of an orthoclase, for example adularia,

$$K_2Al_2Si_6O_{16} + 8H_2O \text{ (liquid)} \rightarrow$$
$$6SiO_2 + 2Al(OH)_3 + 2(KOH \cdot 2H_2O),$$

proceeds with an energy expenditure of 45.75 kcal.

When fibrolite decomposes,

$$Al_2SiO_5 + 3H_2O \rightarrow 2Al(OH)_3 + SiO_2,$$

the energy expenditure amounts to 40.21 kcal.

Knowing these values for the energy expenditures in individual weathering reactions, we can assume the energy expenditures in soil formation in cases where the mineral conversion process penetrates deeply enough. However, it is known that it is just this kind of deep mineral conversion which is characteristic of soils of the moist tropics. In the formation of tropical krasnozems and laterites, the decomposition of minerals to the following products is of predominant importance:

$$SiO_2, Al_2O_3, Fe_2O_3 \text{ and others.}$$

To determine the actual energy expenditures when minerals are transformed in the soil, we must know the rate of this process. To resolve this question, let us use the data on the accumulation rates of component moisture in soil formation (5). We succeeded in establishing, in very general terms, the amount of moisture (P_k) used per year in the new formation of minerals and organic matter and in the formation of plant material. The value changed consecutively according to the hydro series: the hydro series A,AB, B,BC, C,CD, D,DE, E,EF, F,FC correspond to a P_k in mm. per year of 0.02, 0.06, 0.12, 0.22, 0.38, and 0.60.

It is natural that, as a result of the great temperature differences within the limits of each hydroseries, the nature of the component water relations will also be quite variable. Under some conditions moisture absorption will be predominantly for the formation of organic components; under other conditions it will be for the formation of minerals. It can be granted that under moist tropical conditions of soil formation, with their exceptionally intensive mineral conversion processes, the greater part of the component moisture will combine with the mineral substance to form chiefly the end-products of mineral decomposition. Consequently, we can consider approximately that under moist tropical soil-forming conditions the annual increase in component moisture is accounted for, in the last analysis, by mineral weathering process.

Assuming that about 40 kcal. are expended on the destruction of silicate minerals, we find by calculation that 280 cal. of bound energy are required for every gram of water taking part in the weathering reaction. The latter figure may be accepted as a starting point for subsequent calculations. On the basis of this and of the values for the increase in component moisture in the hydro series, it is easy to determine the energy expenditures on mineral conversions in equatorial-tropical soil formation, that is, in thermal series VII, and in soil formation under less moist conditions. But for the sake of complete calculation, we must explain the expenditures of energy on the conversions of minerals at lower mean temperatures.

To resolve this problem, apply van't Hoff's law which states that with a temperature change of 10° C. the reaction rate increases (or decreases) doubly.

Under soil formation conditions, which may be described as a general kind of hydrothermal system, the relative reaction rate may be represented as changing from 1 (at −20° C.) to 32 (at 30° C.). Using van't Hoff's law and the values of the energy expenditures according to the hydro series under thermal group VII conditions, we can find the possible expenditures of energy on mineral conversion under the entire range of hydrothermal conditions. Figure 3, which was compiled according to these data, is quite regular.

The data obtained show how small a part of the energy is expended annually on mineral conversion: it amounts to about 0.2 to 0.5 cal. per cm.^{2} per year under tundra and desert conditions and up to 10 to 15 cal. per cm.^{2} per year under moist tropical conditions. There is nothing unusual in this conclusion. The slow course of geological processes, including weathering, is generally recognized.

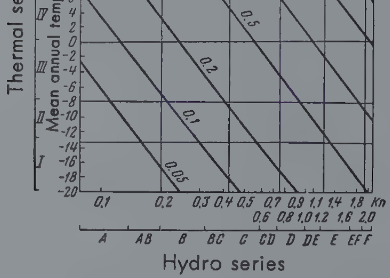

FIG. 3.—Energy expended on the decomposition of minerals in the weathering process in cal. per cm.^{2} per year.

Let us touch on one more of the energy expenditures which go into the soil-forming process —the energy expended on the migration of substances with gravitational water. Here we encounter difficulties which prevent us from approaching any reliable calculation. These difficulties are caused by 1) the impossibility of separating the flow into percolation and surface run-off; and 2) the lack of a clear method for determining the extent of vertical migration pathways of matter although this concept can be used as a basis for determining the amount of mechanical work related to the migration process. To provide some clarification we will cite only the following data. With a percolation rate of 250 m.^{3} per hectare per year, which is possible with adequate moisture, and assuming the migration of substances to a depth 2 m. below the surface, the energy loss will amount to about 2 cal. per cm.^{2} per year. The total amount of energy thus expended is great, but it is a fairly small component of the annual balance and is comparable to the equally small amounts of energy expended on weathering. We are therefore able to make a comparative but approximate estimate of the energy expenditures in soil formation and to describe how they change in relation to the three basic groups of energy expenditures—evapotranspiration, biological processes and weathering. Of course, the weathering processes are also not abiotic. Strictly speaking, a considerable part of weathering energy should be considered as "biological" and separated from the total energy of the biological processes. However, at this stage we must obviously confine ourselves to relative characterizations. By adding the values of each of these kinds of energy expenditures in an adequate number of the hydrothermal system aspects, we arrive at the graph showing total energy expended on soil formation (Fig. 4). These energy expenditures show extreme differences within the limits of the natural variations of hydrothermal conditions. They are naturally minimal under tundra and desert conditions, where they amount to only 2000 to 5000 cal. per cm.^{2} per year, and very large under moist tropical soil-forming conditions where they reach 60,000 to 70,000 cal. per cm.^{2} per year. Forest soil formation in the temperate zone and on the steppes is characterized by expenditures of the order of 20,000 to 40,000 cal. per cm.^{2} per year.

The graph of the energy expended on soil formation, with its regular isometric patterns, also serves as a graph expression of the relative rates of soil formation. If we judge by the amount of energy taking part in soil formation, the rate of soil formation under moist tropical conditions is about seven times as high as in tropical deserts; but the energy expended on soil formation under conditions of high moisture increases relatively by more than twentyfold in passing from the tundra to the moist tropics.

A comparison of the relative energy expended on the basic elements of soil formation is extremely interesting. Appropriate calculations show that by far the greater part of the energy is expended on evapotranspiration phenomena, which absorb 95 to 99.5% of all soil formation energy. About 0.3 to 5.0% is expended on biological processes and in most cases it amounts to only about 1% of the total energy of soil formation. The mineral decomposition of soil-forming rock uses up only hundredths thousandths of a percent of all the soil formation energy. From a very general point of view the relative amounts of energy expended on the evaporation, biological processes and mineral decomposition involved in soil formation can be represented by the ratio 100:1:0.01. No matter how great the differences between the relative amounts of energy expended on the basic soil-forming processes, they can be compared under various hydrothermal conditions in order to draw some conclusions regarding the unique features of soil formation in different zones.

The soil-forming process takes place with the least efficiency (as judged by the expenditure of energy on evaporation under conditions of insufficient moisture or heat) when the expenditures on biological processes and mineral conversion amount to less than 1%. Moist tropical conditions, in which more than 4% of the energy is expended on biological processes, are distinguished by their high efficiency.

The amounts of energy characteristic for most conditions and expended on biological processes are of the same order as the relative energy in photosynthesis, which uses only $\frac{1}{50}$ to $\frac{1}{100}$ or even $\frac{1}{1000}$ of the energy of the absorbed solar radiation. If we were to calculate the portion of energy expended on the formation of plant matter in relation not only to the energy of soil formation, but of the sum total of the incident solar radiation, we would get just these values—of the order of hundredths and thousandths of the energy expended on organic synthesis. One can notice a fairly continuous increase in the relative fraction of the energy expenditure on weathering in passing from less to more moist hydro series.

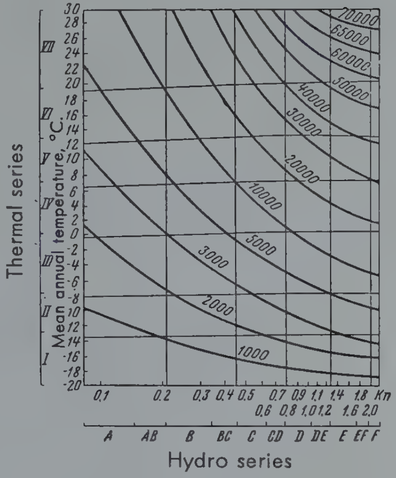

Fig. 4.—Total energy expended in the processes of soil formation in cal. per cm.^{2} per year.

Thus, even this first attempt to examine the energetics of soil formation, regardless of its lack of detail and its obviously qualitative character, has enabled us to shed some light on certain extremely interesting aspects. The conclusion will be justified that research in this field is promising. Research on the seasonal phases of soil formation in particular would be of very great interest.

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BOG SOILS OF ARMENIA AND THEIR PRACTICAL USE

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In the mountain districts of the Armenian Soviet Socialist Republic there are broad areas of bog soils which, as a result of the progressive accumulation of organic matter and the preservation for centuries of plant nutrients, have been converted into a source of potential fertility. Because of the unfavorable conditions existing in bog soils they have hardly been used at all until recently.

Bog soils are located chiefly on the broad Loriysk steppe, in the Sevan basin, and in the Kirovakan, Gukasyan, Krasnosel'sk, Spitak, Aparan and other districts of the Republic. They are usually associated with regions of the lower courses of mountain rivers and streams which form broad flood plains composed of thick alluvial deposits underlain by original rock. Armenian bog soils are fed chiefly by the considerably mineralized ground and river water. In this category, for example, are the massive bogs of the Basargechar plain, the large Sultanabad bog in the Gukasyan district, a considerable part of the large Fioletogo-Gamzachimansk bog in the Kirovakan district, and so forth. On the elevated peripheral portions of these bogs, on which old terraces are located and which blend into the adjoining mountain slopes, for example "Kochki" and "Bol'shoy meadow" of the large Fioletovsk bog (Kirovakan district), an important part is played by emerging subterranean water.

On some tracts, for instance on the northern part of the Loriysk steppe (large Dzhiginsk bog), surface water plays the most important part in the supply of bog soils; the water flows in this direction from the slopes of the more elevated parts of the adjacent mountains and is absorbed and retained by the soddy and peaty material of the upper bog soils.

Another important group of Armenian bog soils is caused by the gradual growth of separate, enclosed bodies of water in the depressions between mountains and in other depressions which are very often encountered on the lower part of the Loriysk steppe, for example on the Saratov tract, at Novosel'tsov, and so forth. This category of bog formation also includes separate areas around lakes, for example Sevan-Ordaklu, which originate from the growth of shallow inlets and quiet bays on the shores of Lake Sevan, where dark gray clayey material of the sapropelite type with a high content of organic matter is formed from the combination of the anaerobic decomposition of the littoral plant and animal residues with the lacustrine alluvium.

Finally, there is a third group of bog formations in Armenia which are located on mountain slopes (for instance, on those of the Karakhach massif) and which receive their water from springs and runoff, since the ground water lies very deep here.

All these large bog areas of the Armenian mountain districts are located within the chernozem zone at altitudes of 1600 to 2000 m. above sea level, scattered throughout the Armenian volcanic highlands, and are composed basically of Quaternary andesitic basalts and their weathered products. Located at a fairly high altitude and surrounded by mountain ranges, the Armenian highlands are quite warm in summer and very cold in winter. The mean annual temperature is 5° to 6° C. and the annual precipitation is 450 to 550 mm. In all the Armenian highland districts mentioned previously, the bog soils adjoin chernozems. In a process of natural self-improvement they gradually go over into chernozems or closely related soils.

The plant cover of these bog soils on peat bogs consists predominantly of sedges, in many cases with thick growths of *Carex graoilis, C. dil., C. acuta, Phragmites isiaca, P. communis, Equisetum palustre, E. heleocharis, Scirpus lacustris, Heliocharis palustria, Myosotis caespitosa, Polygonum monspel, Mentha longifolia, "luncus lampocarp,"* sometimes *Thipha latifolia,* green mosses, and so forth.

In some districts (for example, Basargechar), sedges and reeds predominate; in others there are, in addition, considerable quantities of green mosses (as in Fioletovo), and in still others (Gukasyan) there are no mosses at all. Nowadays only small growths of reeds are found, but at depths of one to two meters observations are often made of large numbers of half-decomposed remains of the stalks of these reeds which are more than two to three centimeters in diameter (at Kirovakan and Basargechar). This shows that reeds were previously located here in far greater numbers and in larger colonies than at present. We are, therefore, dealing with the gradual drying out of the bogs. Around the edges of the bogs there are *Calamagrostis alba, pseudophrag., Stellaria crossifolia, Hippuris vulgaris, Taraxacum odoratum, Cirsium arvense, Brunella vulgaris, Poa persica, Trifolium spadiceum* and others which are replaced at higher spots in the relief by moist meadow and meadow coenoses in which there is predominance by *Deschampsia caespitosa, Alopecurus ventricosus, Agrostis alba, Trifolium fragiferum, T. repens, Phleum pratense* and others. In contrast to the bogs of the central and northern USSR, hardly any trees are found here. Only on the large Gamzachiman bog of Kirovakan district do we find bog willows growing on sandy-gravelly deposits in the alluvial fans of mountain streams.

Pollen analysis of some of the Armenian peats (made in the laboratory of the Moscow Peat Institute under the direction of Prof. Tyuremnov) showed, in addition to sedge and reed, rare isolated examples of the pollen of pine, birch, hornbeam, beech, oak and, especially, examples of diatoms.

Hillocks on the surface of Armenian bog soils are in general quite noticeable, but they are usually formed because of the action of dense bushes and rhizomes and are not high.

The bog soils of the Armenian highland districts are fairly young; in many cases they lie on alluvial and talus deposits underlain by native Quaternary volcanic rock. The youth of the Armenian bog soils is shown by the fact that they are relatively thin and have a low organic matter content. Their ash content varies from 30 to 40%. The fairly high mineral content of the ground and river water by which they are fed leads to the formation of lowland sedge-reed type of bogs. Armenian bog soils, which are in general peaty, reach an average thickness of one to two meters. In many cases they are less than one meter thick and on some tracts where there is commercial peat cutting they are more than a meter thick.

The parent material on which the bog soils have developed consists of sandy clay loam, fine clay and clay loam alluvial and sometimes colluvial deposits which attain considerable thickness in some places. The water table is at a depth of 0.5 to 1 m., depending on the nature of the terrain and the development degree of the bog-forming process, but in some cases it is almost at the surface. Over a period of years we have observed that a superficial water table occurs mostly in the spring in Armenia, while in the summer and fall months—August and September—the water table is at the greatest depths.

Basic sub-groups of Armenian bog soils are distinguished according to how pronounced the bog-forming process is, the accumulation of peat material and its character, and also by the degree of gleying. These sub-groups are genetically interrelated and represent separate stages of development of a single bog-forming process:

Peat-bog soils
Peat-gley soils
Peaty-clayey-bog soils
Bog-meadow soddy soils
Swamped moist meadow (or chernozem-like) soils

Peat-bog soils include those in which a fairly thick stratum of peat material, rich in organic matter, lies directly on gleyed mineral subsoil.

The term peat-gley soils is used to designate those bog soils in which the thickness of the peat is less than 30 to 40 cm. and the upper 20 cm. of the horizon contains some rootlets, which, in the lower, darker part, are more decomposed. The peat stratum is underlain by a distinctly gleyed stratum with pronounced ocherous spots.

The peaty-clayed-bog soils include those in which a thin (5 to 10 cm.) peat layer containing half-decomposed plant remains goes over directly into well-decomposed material which is strongly contaminated by clay and has a high concentration of humus, and which is underlain by a fairly elevated, strongly gleyed stratum.

Bog-meadow soddy soils are characterized by their dark, sodded upper stratum which contains a large number of rootlets and a considerable amount of humus and in which can be seen the accumulation of organic matter. This stratum is a gleyed stratum with many rust-colored spots.

Finally, swamped, moist, meadow soils are distinguished by a conspicuous sod layer on top and a somewhat increased humus content in the upper strata with only slight indications of gleying below.

The most widely distributed bog soil sub-groups in the Armenian highland districts are bog-meadow and especially peat-bog soils; they are of particularly great interest. Swamped, moist, meadow soils occupy considerable areas in which their specific characteristics are shown to varying degrees. The remaining sub-groups are transitional and occupy only a small area.

The following is a description of a peat-bog soil with a sedge-moss cover saturated with water almost to the top:

Profile 12 (Fioletovo-Gamzachiman bog, Kirovakan district)

0–10 cm. Brown to cinnamon brown, slightly decomposed, elastic, wet, with many half-decomposed remains of sedge and moss. Transition abrupt.

10–40 cm. Black, wet, relatively more decomposed, peaty; contains foreign matter and many remains of roots and rhizomes; gives a positive reaction for ferrous oxide.

40–90 cm. Cinnamon brown to brown, somewhat lighter in color, well decomposed; fairly noticeable indications of plant remains which disappear on rubbing; wet.

90–140 cm. Almost the same, but somewhat more wet, well-decomposed peat; contains the remains of reeds which quickly turn dark in air. Transition fairly conspicuous.

140–180 cm. Black, friable, well-decomposed peat; wet; larger reed remains observed.

180–200 cm. Cinnamon-brown to brown peat (like the third stratum). Wet, well-decomposed; contains reed remains. Abrupt transition to subsoil.

200–220 cm. Dark gray, sticky, clayey-gravelly gleyed mineral subsoil with noticeable traces of ocherous iron.

Profiles 1, 2, 3, 4, 34 and others taken from the same tract have similar structures. These profiles contain a fairly thick stratum of peat, attaining two meters. In the structure of the peat deposits here, as in a number of other cases, a definite stratification is observed: dark layers of sedge usually alternate with lighter ones associated with reeds. In places, the peat deposits are covered with a layer of mineral soil sometimes having a thickness of up to 0.5 m. (Gamzachiman). This is also true when the peat layers are separated by thin strata of such soil, sometimes forming two or even three series of peat layers.

Table 1 gives analytical data characterizing the chemical composition and physical properties of Armenian bog soils.

As seen from Table 1, the total amount of organic matter in the peat horizons reaches 80 to 90%. It is noteworthy that in a number of cases the upper strata of peat-bog soils contain considerably less organic matter (up to 35%) because of the admixture of earthy material and mineral soil. Kirovakan, Basargechar and Stepanavan peats have the highest organic matter content. The ash content of peat-bog soils varies within fairly broad limits—from 10 to 65%—and generally averages 30 to 40% in large bogs, which is fairly high. Such a high ash content naturally lowers the value of peat as fuel, but it is of advantage in tillage and cultivation.

The data from the acidity determinations (Table 1) show that, unlike the bog soils of Belorussia, Moscow, and other regions of the USSR, in Armenia these soils have a weakly acid reaction. Bog soils with a pH higher than 7.0 are found in some cases, for example, in Basargechar. This is caused by the accumulation of carbonates and the presence of a certain number of easily soluble salts. The weakly acid reaction of Armenian bog soils makes it unnecessary to use lime for improving them and thus reduces production costs.

As seen from Table 2, Armenian bog-meadow soils differ sharply from the peat-bog soils de-

TABLE 1

Content of organic matter and ash in the peat-bog soils of Armenia (in %)[a]

Profile No.	Depth, cm.	Organic matter	Ash %	pH of water extract	Name of district and altitude of location
12	0–10	35.0	65.0	6.6	Kirovakan, 1750 m. above sea level
	10–40	50.0	50.0	6.6	
	40–140	90.7	9.3	6.7	
	140–180	90.8	9.2	6.7	
	180–200	71.0	29.0	6.7	
13	0–12	57.0	43.0	6.7	
	12–40	87.0	13.0	6.8	
61	0–50	86.8	13.2	6.6	
	50–120	79.7	10.3	6.7	
113-B	0–30	64.4	39.6	6.6	Basargechar, 1940 m.
	30–120	87.1	12.9	6.7	
57-A	0–50	60.0	40.0	6.6	Gukasyan, 2000 m.
	50–100	62.0	38.0	6.7	
76	0–50	76.0	24.0	6.7	Stepanavan, 1450 m.
	50–100	82.0	18.0	6.8	

[a] All the analytical work was done by colleagues in the Department of Soil Science of the Armenian Agricultural Institute.

TABLE 2

Humus and other parameters of the peat-bog soils of Armenia

Profile No.	District	Depth, cm.	Humus, % (Tyurin's method)	pH of water extract	Content of separates, % 0.05–0.01 mm.	Content of separates, % <0.01 mm.
20K	Kalinin	0–12	12.17	6.6	15.37	47.85
		12–30	8.42	6.8	8.63	62.14
		30–52	5.30	7.0	18.35	41.69
		52–78	3.15	7.4	8.44	58.10
66	Kirovakan	0–15	12.74	6.6	12.00	30.22
		15–30	9.20	6.8	12.90	24.65
		30–55	5.40	6.9	11.36	14.72
44	"	0–12	17.5	6.6	12.10	51.13
		12.25	7.0	6.5	15.41	57.20
		25–70	2.0	6.8	13.23	42.14
18	"	0–13	10.25	6.6	14.44	56.22
		13–45	6.87	6.7	16.31	49.30
304A	Krasnosel'sk	0–13	12.56	6.4	14.12	60.31
		13–38	11.30	6.5	10.39	56.62
		38–54	5.13	6.8	8.45	64.08
78	Basargechar	0–9	13.90	6.7	20.50	48.10
		9–18	12.50	6.8	18.40	45.50
		18–48	7.62	7.0	19.50	50.12
53L	Stepanavan	0–12	14.17	6.6	17.13	47.20
		12–28	9.12	6.8	20.10	31.42
		28–42	5.82	7.0	12.65	58.27
59	Gukasyan	0–13	18.90	6.6	22.10	47.55
		13–32	15.55	6.8	17.00	51.14
10M	Martinunsk	0–12	16.90	6.6	—	58.63
		12–27	12.35	6.8	—	58.48

TABLE 3

Total chemical composition of peat-bog soils of Armenia as percent of dry material (analysis by G. Zakharyan)

Profile and sample no.	Fe_2O_3 + FeO	CaO	MgO	SO_3	P_2O_5	Ash	Name of district
34, I	3.42	4.35	1.32	1.88	0.27	19.52	Kirovakan (near source of profile 12)
II	3.51	4.15	1.96	1.93	0.26	18.84	
III	3.42	4.06	2.82	2.15	0.26	17.88	
Mineral subsoil	7.58	4.98	2.46	—	0.01	—	

scribed previously because they have 10 to 18% organic matter; it is in the form of amorphous humus, if we do not consider the roots and undecomposed plant remains. Further, this quantity of humus usually decreases fairly rapidly with depth. The reaction of bog-meadow soils is close to neutral and in many cases it is neutral or even slightly alkaline. The content of the clay and fine silt fractions shows that these soils are representatives of the fine clay loam and clay types. There is a notable absence of any strictly regular pattern in the distribution of the clay fractions vertically along the profile, which is in general characteristic of alluvial deposits.

Table 3 gives the chemical composition of Armenian peat-bog soils. It shows the fairly high content of iron, calcium and magnesium.

The total nitrogen content of these soils reaches 2 to 3%, while that of potassium is 1 to 1.5%. As a result of biological accumulation in the peat layers, fairly large amounts of phosphoric acid and sulfur accumulate there too. Because Armenian bog soils are supplied with a high mineral content by ground water, we have observed the local occurrence of very large accumulations of calcium carbonate, as a result of which calc-sapropel is formed (northwest shore of Lake Sevan). It should also be noted that the increased ash content of the peat and the high content of calcium, magnesium and other compounds are caused in part by matter which is deposited by wind and water and which reaches the bog area regularly.

Chemical analyses of the water-soluble compounds of some Armenian bog soils (Table 4) confirm that these soils very often have a weakly acid reaction caused by the presence of bicarbonates. In some cases there are even regular carbonates (soda). Fairly high alkalinity was detected in profile 26—up to 0.02%. It is caused by the considerable amount of carbonate which in turn is the cause of high mobility of the easily soluble organic substances. The concentration of chloride is also notably high.

The presence of saline spots is one of the specific characteristics of the large areas of bog soils in the Sevan basin. A certain amount of caution is required for the reclamation of these soils by chemical methods. The chemical composition of the ground water shows that it is in general not saline since the concentration of mineral salts—the residue from ignition—does not exceed 1 gram per liter except in the Basargechar area where it is somewhat higher.

As mentioned previously, Armenian peat-bog soils contain a fairly large amount of organic material—peat. These soils show very large differences in the degree of plant residue decomposition; around the edges of large bogs the peat is only slightly decomposed, but nearer the center the structure of the plant residues becomes less clear and a certain amount of amorphous humus can be observed. When the peat is

TABLE 4

Chemical composition of water-soluble compounds of some bog soils of Armenia (in percent)

rofile No.	District	Depth, cm.	Solid residue	Residue on ignition	Loss on ignition	Alkalinity due to		Cl^{-}	SO_4^{--}
						CO_3^{--}	HCO_3^{-}		
17A	Kirovakan	0–15	0.375	0.089	0.286	—	0.012	0.0140	None
		15–35	0.310	0.070	0.240	—	0.009	0.0087	
79	Stepanavan	0–12	0.499	0.100	0.399	—	0.0244	0.0148	
		12–30	0.150	0.050	0.100	—	0.0137	0.0054	
151	Basargechar	0–10	0.722	0.343	0.379	—	0.032	—	
		10–30	0.560	0.206	0.354	—	0.029	—	
26	Nor-Bayazetsk	0–12	0.500	0.150	0.350	0.0036	0.0244	0.1704	
		12–22	0.600	—	—	0.0060	0.0220	0.0497	
		22–75	0.800	0.400	0.400	0.0012	0.0110	0.1005	
145	Basargechar	0–10	0.844	0.375	0.469	—	0.0210	—	
		10–23	0.547	0.224	0.323	—	0.0280	—	
			Ground water, gm. per liter						
79	Stepanavan	—	1.99	0.50	1.49	—	0.21	0.007	
13	Kirovakan	—	0.96	0.70	0.26	—	0.200	0.002	
145	Basargechar	—	2.15	1.35	0.80	—	0.320	0.013	

ueezed a turbid, colored liquid emerges. The ick peat formations of the central part of rge bogs contain more amorphous humus and e structures of the plant residues here are al-ost indistinguishable. The same change in the egree of plant residue decomposition in bog soils observed vertically along the profile. In most ses the upper layers contain relatively little ecomposed material while with depth the degree f plant residue decomposition increases sharply, metimes reaching 60% (at Fioletovo). The verage degree of peat material decomposition the Armenian bog soils is 30 to 40%. It is quite ear that peat soil with only slightly decomposed lant residues abundantly interwoven with a ick network of sedge and grass roots and rhi-omes is very cohesive. When such soil is tilled, latively greater pulling power must be used.

Let us consider some of the data characterizing e physical properties of the Armenian bog soils hich we obtained from laboratory investigations Gamzachiman-Fioletovo, Kirovakan district).

Table 5 shows that with a fairly high organic atter content, the bulk density of Armenian eat-bog soils varies from 0.12 to 0.23, except in rofile 4, in which it rises to 0.46 because of the igh mineral material content in the upper layer. he particle density of these soils varies between e fairly narrow limits of 1.45 to 1.50. An exception to this is Profile 4 again in which the particle density of the top 20 cm. layer is considerably higher because of the reasons given. There is no strict relationship between the content of organic matter and the bulk and particle density. This is because the latter parameters depend not only on the total amount of organic matter but also on the degree of its decomposition which, as shown previously, varies within extremely wide limits in different strata and profiles.

The degree of decomposition of the peat also

TABLE 5

Some physical properties of the peat-bog soils of Armenia

Profile No.	Depth, cm.	Organic matter, %	Bulk density (av. of 10 det'd.)	Particle density (av. of 10 det'd.)	Pore space when dry, %	Field moisture (av. of numerous det'd, %)
1	0–28	77.0	0.22	1.47	83	80–90
	28–36	82.0	0.18	1.50	84	82–88
	47–57	80.0	0.17	1.45	88	86–90
2	0–20	80.0	0.12	1.44	90	75–93
	20–40	75.0	0.17	1.47	86	83–90
	40–70	80.0	0.19	1.47	87	86–90
3	0–20	82.0	0.12	1.51	92	81–94
4	0–20	25.0	0.46	1.87	75	60–80
	27–35	72.0	0.23	1.54	85	83–90
	45–56	74.0	0.18	1.49	87	87–89

governs another extremely important property of bog soils—their pore space. Table 5 shows that the pore space of peat-bog soils when dry is 83 to 87%, in some cases reaching 90 to 92%. The field moisture content is 80 to 90% and even more in some profiles. In locations with a high proportion of inorganic particles it goes down to 60%.

Another noteworthy physical property of bog soils is their change in volume. It is understandable that the more organic colloids there are in the soil and the greater the degree of decomposition of the peat, the more the volume will change. Investigation of 16 samples of peat-bog soils showed that 500 cm.^{3} samples saturated with water in their natural condition reduced their volume to between 135 and 280 cm.^{3} when they were dried out: that is, the volume decreased by 44 to 73% (Table 6).

As seen from Table 6, in 100 g. of dry peat from the same samples, volumes ranged from 104 to 560 cm.^{3} The weight of 500 cm.^{3} of the same 16 samples of peat bog soils with their natural moisture content varied from 444 to 568 g., and the ratio of the volume of the moist material to that which has been dried varies from 2 to as much as 4. After they had been dried, all these samples of bog soils were brought back up to their full capillary moisture content over a period of week. The results obtained show that duri the swelling process their volume increased i significantly by a factor of 1.06 to 1.82. In mo cases after saturation with water the volume the sample of peat-bog soil being investigat reached 50 to 60% of initial volume and, in on a few cases, 70 to 80%. In some cases the volu of the soil which had been dried and remoisten increased very little after swelling—to only to 38% of the original volume (Profiles 6 an 16). Thus, not one of the 16 dried samples peat-bog soils proved to be in a condition to r absorb all the lost water and to reassume th original volume. This shows that when peat dried, profound changes take place in its co loidal fraction. We should not conclude, howeve that whenever peat with a high concentration organic matter is dried, its volume increas only slightly on rewetting, that is, that peat al sorbs water poorly. The degree of swelling peat-bog soils depends not only on the amou of organic matter and colloids, or on the degr of decomposition of the plant residue, but al on the degree of intensity of drying; the latt may materially affect the conversion of colloi and the possibility of their changing into som condition which is irreversible.

TABLE 6

Volume changes of bog soils of Armenia on drying and resaturating with water

Sample No.	Original volume, cm.^{3}	After drying					After resaturating		
		Volume, cm.^{3}	Decrease factor	Decrease in volume, %	Weight, gm.	Volume of 100 gm. of soil, cm.^{3}	Volume in cm.^{3}	Increase factor	As % of original volume
1	500	180	2.77	64	84.2	213.7	295	1.63	59
2	“	175	2.85	65	83.4	209.8	250	1.42	50
3	“	230	2.17	54	71.0	323.09	245	1.06	49
4	“	170	2.94	66	85.9	197.9	310	1.82	62
5	“	155	3.22	69	130	119.2	280	1.80	56
6	“	145	3.44	71	85.9	168.7	155	1.07	31
7	“	135	3.70	73	75.0	180.0	245	1.81	49
8	“	205	2.43	59	75.3	272.2	305	1.48	61
9	“	215	2.32	57	97.7	220.0	315	1.46	63
10	“	240	2.08	52	97.0	247.4	400	1.66	80
11	“	205	2.39	59	62.4	328.5	285	1.39	57
12	“	240	2.08	52	49.0	489.8	335	1.39	67
13	“	280	1.80	44	50.0	560.0	320	1.14	64
14	“	250	2.00	50	57.7	433.2	350	1.40	70
15	“	220	2.27	56	70.0	314.3	250	1.13	50
16	“	165	3.08	67	70.0	231.4	190	1.15	38

This leads to the extremely important pract cal conclusion that in improving and reclaimin peat-bog soils, the question of lowering the w ter table should be approached very cautiousl In the improvement of bog soils the problem do not consist in an abrupt lowering of the wat table so as to prevent access to ground water the root systems of cultivated plants, but rath in a rational regulation of the system of soil moi ture. In this respect all possible measures mu be used to avoid excessive drying out of the b soils when "improving" them, or else the s may lose its ability to absorb and retain an ad quate amount of moisture. It is best to lower t moisture content of bog soils being reclaim to 60 to 70% of their total moisture capacity.

These data show that the bog soils of Armen (because they have a high organic matter co tent, considerable amounts of nitrogen, pho phoric acid, and potassium, and a weakly aci nearly neutral reaction) constitute an importa land resource for expanding the area on whi crops can be sown. After soil-improvement mea ures have been taken which are appropriate f odder and meadow crop rotations, it will be ossible to grow potatoes, cabbage and other egetables, grasses and edible roots for feed, nd grain crops over much of the area. This will nake it possible, after improvement of the large ogs, to establish on them a large area for growng feed for the future development of cattle-aising and for supplying vegetables for the poplations of the nearby cities and industrial enters.

Our experience in the study and reclamation f the bog soils of Armenia shows that large reas of such soils having a smaller amount of eat and a low water table can be converted into ighly productive soils with the aid of only a ew farm practices. Thick peat-bog soils with igh water tables and large amounts of well-ecomposed peat require the previous removal f excess ground water by setting up an approriate drainage network, without which initial illage of these soils cannot be carried out. In lowing such soils in Armenia we undertook, as production experiment, to use full reversal of he furrow slice in some cases, less complete reersal in others, and in still others, initially to aise the upper layer, containing the tangled oot systems of the sod, followed by deep plowng. An important part is played by the number nd intensity of harrowings with toothed or disk arrows. The more these operations are carried ut (the finer the chopped-up pieces of undeomposed sod) the faster it will be converted into ranular soil. According to our observations, here is no very great difference between summer nd fall plowing of bog soils in the Armenian ighlands. In establishing the time for tillage, onsideration must be given to the character of he sod and especially to the degree of decompoition of the peat. Thick, strongly tangled root ystems in the sod-peat material require a comaratively long time for their decomposition, but naterial which is well-decomposed and rich in rganic colloids is converted into granular soil onsiderably faster. As a result of cultivation of ome of the bog soils of the Armenian highlands or two or three years it has been possible to conert considerable areas into tilled fields and arale land which, with good tillage, give very high ields of potatoes, cabbage, grain and forage lants. It is notable that the tillage and reclamaion of these bog soils does not require a large utlay. Under the conditions of collective farm production the capital outlay pays for itself in the first two years.

In a number of places where peat occurs in Armenia and where there is large-scale extraction of peat for fuel (Basargechar, Gamzachiman, Stepanavan), much valuable land is wasted because the surface soil with a considerable amount of organic matter is rejected and thrown to the bottom of the pits. The peat scraps from the pits can be used as litter for cattle to increase the quantity of manure on collective and state farms, and also for the preparation of peat compost, which is a valuable organic fertilizer and plays an important part in raising crop productivity.

In the highland regions of the Armenian SSR, as in a number of other republics and regions of the USSR, there are still large areas of bog soils and swamps which remain unused; for this reason the problem of the improvement and practical use of Armenian bog soils merits close attention.

Conclusions

Bog soils cover large areas of the Armenian highlands. They are located in the zone of chernozem soils at altitudes from 1600 to 2200 m. above sea level. Most of the large areas have peat-bog and bog-meadow soils underlain by alluvial and, in some places, colluvial fine clay loam and clayey deposits. The lowland type of Armenian bog soil receives water from fairly mineralized ground water and is formed from sedge and reed residues. The water table is at a depth of 0.5 to 1.0 m. The average thickness of peat bogs is 1 to 2 m.; the ash content is 30 to 40%; the reaction is weakly acid; the nitrogen content is 2 to 3%, the phosphoric acid content is 0.2 to 0.3%, and the potassium content is 1.0 to 1.5%. The total of readily soluble mineral salts in the upper part of the soil does not exceed 0.2%, and the ground water is also not saline. The bulk density is 0.12 to 0.23, the particle density is 1.44 to 1.54, and the pore space is 80 to 90%.

These soils are of great value since with certain drainage and other improvement measures and appropriate tillage they are converted into highly productive, fertile soils.

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GENESIS OF MOUNTAIN-STEPPE FRAGMENTARY SOILS O KOPET-DAG[1]

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THE area investigated lies in the steppe belt characterized by a desert continental climate—dry, hot summers and cold winters with little snow. The vegetation consists of couch-grass, feather-grass and *Festuca sulcata* associations, alternating on primitive soils with very sparse ephemeral grassy cover of various kinds with a large proportion of tragacanth-type astragali (an association of mountain xerophytes). The structure of the relief takes the form of a series of parallel folds running from southwest to northeast. The height of the folds varies between 50 and 150 m. The steepness of the northwestern slopes fluctuates between 3 and 15 degrees, the southeastern slopes being, as a rule, steeper and reaching 20 to 25 degrees. These folds are called ridges. Between the ridges are located ravines, rarely intermontane dales, the bottoms, of which are composed of loose materials. Each ridge presents a stratum (or several strata) sloping northwest. The southeastern slopes have fractures cropping out of these strata, covered in the lower and middle parts with talus cones and proluvial scree.

The soil-forming rocks of the area are, according to microscopic study of sections, compact clay shales, low in carbonate, of Aube[2] formation. The area investigated lies in the belt where dark sierozems occur. Among the attempts at a classification of mountain soils, the work of K. P. Bogatyrev (1) on the development of fragmentary soils and their classification is especially valuable. Unlike the earlier subdivision using degrees of stoniness, this classification is characterised by a profound genetic approach.

In the area investigated, the occurrence of soils in various stages of development is related to one or another element of the relief. Fragmentary soils of the second stage occur on the crests of the ridges, and of the third stage on the stee northwestern slopes. Soils of the northwester slopes are represented by dark sierozems whic have emerged from the fragmentary state. Thus nature herself made it possible for us to stud the relation of soil development to surface erosion, since the intensity of the latter determine the various stages in soil development. For thi reason we were able to trace in one and th same zone and on one and the same rock single evolutionary chain of fragmentary soi development.

Fragmentary Soils of the First Stage of Development

First stage soil formation takes place alon cracks in the rock, sometimes down to a considerable depth. The lower limit of the root occurrence of mountain xerophytes along crack was observed at a depth of 5 m. Up to thi depth an accumulation of organic-mineral matter occurs along the cracks in the rock. An uppe humus horizon is not necessarily present.

The total chemical composition of fine eart and of *fragmentum* (rock) is alike, which i typical both of little-developed soils and of th sierozem-forming process in general (5).

The formation of the soil profile begins onl at the second development stage, when th humus horizon is taking shape. K. P. Bogatyre also refers to this, noting that properties o fragmentary soils are shown most clearly at th second stage of development. Possibly one shoul consider the first and the second stage unde our conditions as two phases in first stage development.

Fragmentary Soils of the Second Stage of Development

These soils occur on the tops of the ridges Their vegetation consists of sparse association of mountain xerophytes.

An extremely small amount of broken stone (detritus) in comparison with the subsequen stage is typical of the profile of these soils, in spite of their shallowness (15 to 30 cm.) See Tables 1 and 2. This is explained by the fact that the humus horizon is formed directly on the rock. Evidently intensive weathering also takes place.

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[1] The data for this paper were collected in 1953 at the camp of the Turkmeno-Transcaucasian expedition of the V. A. Komarov Botanical Institute, Acad. of Sciences, USSR, in western Kopet-Dag, 1600–1700 m. above sea level.

[2] Al'b, Russian term taken from French river.

We give a description of profile 8 under sparse vegetation consisting of mountain xerophytes:

0–2 cm. Layer of fine broken stones.
2–13 cm. Grey clay loam, in layers, with fine pores, with few broken stones. Transition marked.
13–33 cm. Coarse slabs of rock, wide cracks filled with fine earth of cinnamon color with a greyish tint. A large concentration of roots along the cracks. Fresh, does not effervesce.

Of great interest in fragmentary soils is the presence of a surface horizon of fine broken stones in 2 to 3 layers, of fairly uniform size—1 to 2 cm. though they do not invariably occur. As a result of soil erosion the broken stones gradually approach the surface of the profile, as if floating up. Emerging from the more or less moist soil layer to the surface and being now under dry conditions, the broken stones cease weathering, whereas in the soil profile their disintegration continues and they frequently completely disappear. A soil-protecting cover of this kind is the remains of a former broken-stony soil.

The most indicative morphological distinction n the second stage of the fragmentary soils of Kopet-Dag is the cinnamon color of the fine earth. In soils of the third stage (described below) the fine earth already has a grey color without any cinnamon tint. This cinnamon fine earth occurs directly on the rock and along the cracks in it. For the humus horizon of the second stage of fragmentary soils the following differentiation into two subhorizons is characteristic: grey fine-porous clay loam in the form of a crust and below it cinnamon clay loam.

The distribution of humus is worthy of attention. The amount does not diminish but even ncreases somewhat with the depth. A similar phenomenon has been noticed in the literature (1, 3). An increase of this kind is connected with the distribution of the root system. Its density sharply increases when in contact with rock. The occurrence of cinnamon fine earth described previously is related to this layer of maximum root concentration.

TABLE 1

Data from chemical analyses of fragmentary soils in the second stage of development

Profile No.	Depth, cm.	Humus, %	Total N, %	C:N	CO_2, %	pH in water	Hygroscopic moisture, %	Stoniness, %
8	0–10	1.25	0.14	5.0	0.24	7.7	1.85	22.6
	10–20	1.47	0.16	5.3	0.27	7.7	2.17	3.6

TABLE 2

Data from chemical analyses of fragmentary soils in the third stage of development

Profile No.	Depth, cm.	Humus, %	Total N, %	C:N	CO_2, %	pH in water	Hygroscopic moisture, %	Stoniness, %
11	0–10	2.68	0.23	6.7	0.21	7.8	2.40	50
	10–20	1.99	—	—	2.13	7.8	2.25	81
	20–30	2.14	—	—	2.10	7.9	2.38	82
	30–40	1.64	—	—	8.62	7.8	1.90	60

Fragmentary Soils of the Third Stage of Development

Soils of this stage occur on the steep northwestern slopes under *Festuca sulcata* vegetation with an admixture of some types of mountain-xerophyte association.

The profile of these soils is characterised by the gradual nature of its transitions, fairly loose compaction, and ill-defined structure. The filling of the cracks in the rock with carbonates indicates that they are fairly well leached.

These soils are illustrated by profile 11:

0–10 cm. Grey loose clay loam, penetrated by roots, of unstable crumb structure, broken-stones. Transition gradual.
10–30 cm. Lighter color than the upper layer, more broken-stones. Effervesces at 15 to 20 cm.
30–40 cm. Fine earth-whitish from carbonates. Carbonates in the form of filaments and films along the bottom of the fine broken-stones layer.
40–130 cm. Rock, split into slabs, increasing with depth. Some cracks (3 to 5 cm.) have an uninterrupted filling of carbonates.

The increase of broken stones in the profile compared with the soils of the second stage is connected in our opinion with the fact that the decomposition of the broken stones occurs not in the transitional zone (as the humus horizon in

TABLE 3

Data from the chemical analysis of dark sierozem

Profile No.	Depth, cm.	Humus, %	Total N, %	C:N	CO_2, %	pH in water	Hygroscopic moisture, %
23	0–10	2.34	0.20	6.79	1.97	8.5	1.94
	10–20	1.59			6.54	8.1	1.96
	20–30	1.00			11.8	7.9	1.53
	45–55	0.55			12.0	8.0	1.69
	60–70	0.35			12.1	8.0	1.39

soils of the third stage is underlaid with a transitory, less biologically active horizon B), but only in the humus horizon.

Two phases of rock decomposition are noted: 1) formation of broken stones, and 2) its subsequent decomposition. In our case, on sedimentary easily-weathered rocks, the formation of broken stones proceeds fairly intensively. Compact rock (clay shale) disintegrates into thin slabs, which subsequently fall to pieces, through a network of vertical cracks, into broken stones of fairly uniform size. A similar decomposition process takes place not only in the soil profile, but also on the rocky outcrops of the parent material.

In the humus-accumulative horizon, the humus content reaches 2.7% and decreases with depth. The amount of CO_2 increases from 0.21% in the upper horizon to 8.62% in the lower.

Dark Sierozems (Zonal Soil)

These soils occur on the northwestern slopes. The grassy cover consists of a *Festuca sulcata* association.

The characteristics of dark sierozems are clear differentiation of the horizons, almost complete lack of broken stones, extremely stable structure and high carbonate content. They are zonal, but occupy a small percentage of the area studied, whereas fragmentary soils predominate.

The morphological build-up of the profile of these soils is illustrated by profile 23:

0–15 cm. Grey clay loam knitted together with rootstocks and roots into loose sod, of fine-blocky structure. Effervesces at the surface. Transition gradual.

15–35 cm. Clay loam lighter color than the preceding, with a pale yellow tint, blocky, compacted, mottled with carbonates. Transition gradual.

35–60 cm. The same clay loam with a yellowish tint, medium clay loam, with coarse bloc units, compacted. Abundance of carbonates the form of white concretions, flecks and vei

60–100 cm. The same, more compact. Brok stones appear with a film and channels of ca bonates below.

The humus content in the upper horizon (0 10 cm.) reaches 2.34% and decreases fairly un formly down the profile. The CO_2 content in th upper horizon is 1.97%, increasing up to 12.1 in the carbonate-illuvial horizon.

We shall deal in detail with the genetic change of soils during their development from shallo primitive soils to zonal soils with develope profiles.

Under mountain conditions, excluding th areas of renewed erosion, fine-earth erosion as sumes a more or less uniform character, and th surface of mountain soils is rejuvenated wit varying intensity under various conditions. Th process of 'rejuvenation' appears not to be soil destroying, but the normal result of erosio process—a result most clearly expressed i mountain soil formation and negligible in th soils of plains. I. P. Gerasimov (2) noted tha the process of denudation represents an inseparable part of soil formation as a whole (eluvia in the first place).

Side by side with 'rejuvenation'—by surface erosion—is the process of deepening of the soi profile through weathering of the soil-forming rock with the active participation of living organisms. Owing to this the development of soil takes place—their emergence from the fragmentary stage. Thus, the balance is established between the rate of surface erosion and the deepening of the soil profile by means of disintegration o fragments of hard parent rock during the process of weathering. The result of these two processe is a definite thickness of the soil profile, a definite stage of development of fragmentary soils. I the fine-earth erosion under the given condition proceeds at a more or less equal rate, then the rate of the second process reaches its highest point in the humus-accumulative horizon, as the most biologically active, and decreases fairl sharply with depth. Thus, choosing a number o slopes of increasing steepness, we found a serie of soils with an ever increasing degree of 'rejuvenation'. We regard such a series as an unique evolutionary chain consisting of formations o different ages.

The first, and, more especially, the second, development stage of the Kopet-Dag fragmentary soils are characterised by the accumulaion of root mass at the point of contact with he rock. The increase of humus content with depth is connected with this. The fine earth at hese stages is more moist than in soils with a developed profile. All this leads to more intensive weathering of the rock, which is reflected in the ow degree of stoniness of the second development stage. Thus, in the second stage, the rock decomposition rate and the profile formation rise most rapidly.

Second stage soils are, as a rule, low in carbonate. With soil development the transition s observed from primitive soils with no, or little, carbonate content to developed soils of high carbonate content. This phenomenon, in our opinion, is connected primarily with the thickness of the soil profile and hence with its capacty to retain in wet seasons a certain amount of moisture. Fragmentary soils of small profile hickness will obviously be saturated every year right through and will lose a certain amount of soluble salts.

The change of the sparse association of *Festuca sulcata* mountain xerophytes leads to surface sod-formation, to the decrease of surface erosion and, consequently, to the increase of the profile thickness. This phase is the third stage of fragmentary soil development. The vegetative root system no longer accumulates at the point of contact with the rock. The gradual decrease with depth of the humus content is associated with this.

The soil profile of third stage is mostly stony. The point is that, owing to the continual 'rejuvenation', the fine earth of the preceding stage may not be included in the subsequent profile. Surface erosion and the deepening of the profile proceed continuously, the latter process being more vigorous, which results in an increase of the profile thickness. The process of fine earth formation at the point of contact with compact rock goes on under less active biological influence (no relative humus increase or root mass accumulation occurs in the lower part of the profile). Associated with this is the decrease in the intensity of weathering of broken stones at the point of contact with rock. Owing to the continuous surface erosion the broken stone floats up, as it were, to the surface and disintegrates not at the point of contact with the rock but at the borderline of the humus horizon.

Already on the zonal stage of development, having emerged from the fragmentary state, the next soil is the dark sierozem. These soils occur on the slopes, where owing to the slight gradient and the dense grassy cover, the erosion is only on a very small scale. The whole moisture cycle proceeds within the developed profile of dark sierozems, a result of which is an increase of the carbonate content. The ascending moisture flow during the period of summer drying-up, resulting in the enrichment of the soil profile with carbonates, acquires great importance in the water regime.

Thus, in the first stages the rate of rock disintegration and, subsequently, of soil profile formation, increases most rapidly. As the soil-forming process develops, a rise in the humus contents takes place and an increase of plant mass per unit of soil surface, that is an increase of natural soil fertility. We approach closely the conclusion of A. A. Rode (4) "The rate of the soil formation process decreases with time", giving for our particular case, however, a somewhat different formulation: in the initial stages the series of soil formation processes take place more intensively. Commencing with the early stages, the soil evolves, changing in the course of time (at a different rate in different stages) from a thin soil layer to soils having the profile already formed. Therefore, the subdivision of the change brought about in soils by time called 'development' and 'evolution' has no foundation. Soil cover evolution under mountain conditions, is on the whole, characterised especially by continuous 'rejuvenation', supporting the soil cover in the early stages of development. In the mountain regions fragmentary soils frequently predominate over developed soils. The typical soil under the conditions described is a skeletal shallow soil under sparse vegetation. But belts of vegetation are formed in patches on developed soils, while the vegetation of fragmentary soils obeys its own laws and is distinguished by uniformity at different altitudes.

The soils of relatively flat surfaces reflect most fully the vertical soil zonality. Here the direct effect of the relief is excluded, whereas under mountain conditions it is a dominant factor in soil formation.

Owing to continuous surface erosion, the law of vertical zonality may not be clearly manifested.

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CHANGES IN THE SALT REGIME AFTER IRRIGATION OF SOLONETZ-LIKE DARK CHESTNUT SOILS ON THE EASTERN VOLGA BANK

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In the sixth five-year plan, large works in irrigation and development of irrigation agriculture were assigned to the Saratov district collective and state farms. With the increase in level of Volga River water accompanying the installation of the Kuybyshev and Stalingrad Hydroelectric Stations there arose the question of irrigating areas close to the Volga banks (second river terrace). Therefore, it was necessary to find out to what extent salinization of these soils could be expected under irrigation and to investigate means of preventing it.

Two fundamental systems are used in irrigated agriculture: fall-charging irrigation and summer crop irrigation. A series of investigations made in various regions of our country (6, 3, 4, 7, 10, 12, and others) have shown that the behavior of easily soluble salts in soils is closely connected with the irrigation system.

Solonetz-like dark chestnut soils with deep water table, widely distributed in the eastern bank, Saratov district, are characterized by an accumulation of easily soluble salts (chlorides, sulfates, bicarbonates) in the lower horizons, beginning at 80 cm. depth. When transported upward in the rising moisture flow during evaporation, these salts may cause a saline root zone injurious to crops.

To clarify the conditions and nature of salt transport in relation to irrigation methods we made special investigations in 1953 and 1954 on irrigated plots planted to spring wheat with different irrigation methods. The experiment was located on the demonstration farm of the Saratov Agricultural Institute on the second terrace of the east bank of the Volga River near Engel's.

Soil samples for chemical analysis were taken with an auger in triplicate before irrigation, after each irrigation, before irrigation in the spring, and after harvest at the following depths: 10, 30, 50, 80, 120 cm., considering the thickness of genetic horizons. In addition, in the spring and after harvest, soil samples were taken at depths of 140 and 160 cm. A composite sample was used for chemical analysis. Each composite sample (analyzed in duplicate) consisted of three soil samples. Samples for moisture determination were taken from the same holes at every 10 cm. up to 60 cm. depth and at every 20 cm. from 60 to 120 cm. depth.

The plot sizes were 750 to 780 m.^{2} in 1953, 470 m.^{2} in 1954. The plots were duplicated. Fall-charging irrigation was made in October by flooding at the rate of 1400 m.^{3}/ha., crop irrigation in furrows at rates of 930 to 1120 m.^{3}/ha.

Moisture determinations on the plots receiving the fall-charging irrigation and on controls showed that at the end of May a significantly greater quantity of water, with more even distribution in the profile, was present after irrigation (Table 1).

In the 1953 experiment the moisture content to a depth of 1 m. was 5.4% higher with charging than without it. The difference in moisture between the upper (0 to 20) and lower (80 to 100) layers with charging was 1.6%, but without irrigation it reached 6.8%; that is, in the former case moisture was distributed more evenly with depth. We observed a similar picture in the 1954 experiment.

The leaching of salts, like their rise into the root zone, depends on the distribution and movement of water in soils. Uniform distribution of moisture in the soil profile favors more uniform distribution of easily soluble salts and reduces the danger of their accumulation in any horizon in amounts harmful to cultivated crops. With strongly developed micro-relief and great variations in moisture in the soil profile, conditions may arise for accumulation of easily soluble salts. Leaching under these conditions may not remove salts from the root zone since they do not move in a continuous flow but as isolated tongues, and unleached portions may remain. With fall-charging irrigation, there are good conditions for leaching salts from the soil

TABLE 1

Soil moisture in percent of absolutely dry soil

Depth, cm.	Irrigation system			
	Fall-charging	No irrigation	Fall-charging	No irrigation
	May 25, 1953		May 22, 1954	
0–20	28.0	24.7	31.2	25.0
20–40	28.3	24.6	29.0	16.7
20–60	27.2	23.1	27.2	17.3
60–80	26.3	18.6	23.5	18.2
80–100	26.4	17.9	21.0	19.3
Average for the layer 0–100	27.2	21.8	26.4	19.3

TABLE 2

Chloride (Cl^-) content with different systems of irrigation in grams per kilogram of dry soil on August 13, 1953

System of irrigation	Depth, cm.				
	0–10	20–30	40–50	70–80	110–120
Fall-charging	0.06	0.04	0.05	0.17	1.31
Fall-charging plus two crop irrigations	0.06	0.05	0.06	0.33	1.58
One crop irrigation	0.12	0.12	0.11	0.62	1.87
Three crop irrigations	0.08	0.07	0.09	0.32	2.53
No irrigation	0.06	0.06	0.07	0.98	2.15

root zone. High mobility of easily soluble salts in the soil profile upon irrigation without direct contact with ground water was established in our experiments. This agreed with investigations of M. V. Preobrazhenskaya (13), M. N. Mikhaylov and I. F. Muzychuk (11), made in the Rostov district.

With improper irrigation, the solubility of salts and their concentration in micro-zones may injure agricultural crops. In Table 2 the chloride content of soils with different methods of irrigation is presented: 1) one fall-charging irrigation, 2) fall-charging together with two crop irrigations, 3) one crop irrigation, 4) three crop irrigations, and a control—without irrigation. Most (95%) roots of irrigated spring wheat were located in the 0 to 85 cm. layer.

According to studies of the Valuyki Experimental Improvement Station, soils with a Cl^- content up to 0.5 gm./kg. are considered weakly saline, with 0.5 to 1 gm. moderately saline, a with more than 1 gm. strongly saline. One fa charging irrigation did not change the chlori content of the upper half meter layer, where was small, but caused a significant reduction this ion (compared with non-irrigated plots) depths of 70 to 80 cm. from 0.98 to 0.17 gm and at the top of the second meter (110 to 1 cm.) from 2.15 to 1.31 gm./kg. of soil.

Thus, under charging irrigation, salt is r moved from the lower soil layers. The use of o crop irrigation showed considerably less salt r moval in the lower horizons than a charging i rigation; at a depth of 70 to 80 cm. chloride were reduced from 0.98 to 0.62 gm./kg. of soi and at a depth of 110 to 120 cm. from 2.15 t 1.87 gm. compared with non-irrigated plots With regard to chloride content charging com bined with crop irrigations gave similar result as three crop irrigations. But at a depth of 11 to 120 cm. charging irrigation showed an ad vantage. Obviously, charging combined wit crop irrigations are most effective on saline soils

Water soluble sulfates accumulating in larg quantities in the root zone may also show depressing effect on irrigated crops. Studies o the Valuyki Experimental Improvement Statio showed that sulfate (SO$_4^-$) in amounts fro 1 to 3 gm./kg. of soil causes some injury t wheat and more than 3 gm. causes serious injury and even death. In Table 3 sulfate (SO$_4^=$) contents are presented for the same dates and methods of irrigation as for chlorides.

As seen in Table 3, sulfate contents along the profile of the experimental soils were similar to chloride contents. In the upper half meter layer little sulfate was found with any method of irrigation. In lower horizons at 70 to 80 cm. depth, sulfates were observed in large quantities only in the control; that is, the non-irrigated plot. In all cases irrigation greatly reduced the sulfate content at this depth (from 6.3 to 0.47–0.33 gm.); from strongly saline with sulfates, this horizon became non-saline. Significant differences between methods of irrigation in the reduction of sulfates at this depth were not noted.

A different picture was seen at a depth of 110 to 120 cm. Following irrigation, sulfates leached from the upper meter layer accumulated in lower layers. This was especially marked with crop irrigations. For example, with one crop irrigation the sulfate content increased from

17 to 10.01 gm./kg. of soil. With charging irri-ation, a lesser increase in content of these lts was observed: from 8.17 to 8.78 gm./kg. of oil. With combined charging and crop irriga-ons, the accumulation of sulfates at 110 to 120 m. was also less than with one crop irrigation. Vith charging, the accumulation in this layer as 9.29, but with three crop irrigations 10.11 m./kg. of dry soil.

Our observations show that the total alkalinity f solonetz-like dark chestnut soils increases ith irrigation, especially with charging irriga-ion. Alkalinity in the root zone of this soil is aused in most cases by sodium bicarbonate, hich constitutes 55% of the total salts at 40 to 0 cm. and 61% at 70 to 80 cm. This salt also lays a conspicuous role in the upper layers with harging irrigation. If the total alkalinity of the ater extract of carbonate soils is caused by bi-arbonates and carbonates of sodium, and is igher than 0.5 gm./kg. of soil, it is considered etrimental to plant life. Throughout its profile, he solonetz-like dark chestnut soil under investi-ation has a high alkalinity from bicarbonates, vhich are highest of all in the lower root zone (70 o 80 cm.).

Irrigation acts differently on soil alkalinity han on the behavior of chlorides and sulfates. Vith all methods of irrigation, a significant in-rease in alkalinity occurs in the entire soil pro-ile: beginning at the surface (0 to 10 cm.), vhere the bicarbonate content increased from .59 to 0.83–0.88 gm./kg., and at the depth of its reatest accumulation (70 to 80 cm.) from 0.78 o 1.20–1.48 gm./kg. of soil (Table 4).

From Table 4 it appears that very important ncreases in alkalinity are observed in the lower oot zone (70 to 80 cm.). Also, fall-charging irri-ation causes greater alkalinity than crop irri-ations. With one charging irrigation the amount f carbonate at this depth increased from 0.78 o 1.48, but with one crop irrigation to 1.20 m./kg. of soil. Combining two crop irrigations vith fall-charging reduced the alkalizing effect: vith one charging irrigation the bicarbonates vere 1.48, but this combined with two crop irri-ations gave 1.29 gm./kg. of soil. With three rop irrigations the least alkalinization was ob-erved compared with other methods of irriga-ion. With this method the bicarbonate content ncreased only in the 70 to 80 cm. depth from 0.78 to 1.04 gm. At the remaining depths increases were insignificant or not observed at all.

TABLE 3

Sulfate ($SO_4^{=}$) content with different systems of irrigation in grams per kilogram of dry soil on August 13, 1953

System of irrigation	Depth, cm.				
	0–10	20–30	40–50	70–80	110–120
Fall-charging	0.29	0.28	0.18	0.37	8.78
Fall-charging plus two crop irrigations	0.24	0.25	0.33	0.33	9.29
One crop irrigation	0.29	0.26	0.24	0.47	10.01
Three crop irrigations	0.20	0.20	0.21	0.46	10.11
No irrigation	0.27	0.24	0.18	6.30	8.17

Thus, increases in alkalinity in the root zone may be avoided by proper combination of charging and crop irrigation. We observed similar behavior of these anions in the 1954 experiment.

A number of explanations have been given for the increasing alkalinity of soils upon irrigation. In the opinion of V. A. Kovda (8), alkalinization of dilute soil solutions is made possible by dissociation and hydrolysis of alkaline earth and alkali carbonates. According to K. K. Gedroits (5), alkalinization is possible because of the entry of sodium into the exchange complex. According to the investigations of E. B. Ablakova (1, 2), during the formation and intensification of alkalinity when flooding rice fields, an important role is played by the reduction of sulfates to volatile H_2S and free NaOH. Finally, in the opinion of M. S. Kurbatov (9), "alkalinization of soils upon irrigation is not determined only by dilution of originally concentrated solutions. It

TABLE 4

Bicarbonate (HCO_3^-) content with different systems of irrigation in grams per kilogram of dry soil

System of irrigation	Depth, cm.				
	0–10	20–30	40–50	70–80	110–120
Fall-charging	0.83	0.86	0.98	1.48	0.58
Fall-charging plus two crop irrigations	0.86	0.86	1.06	1.29	0.58
One crop irrigation	0.88	0.88	1.00	1.20	0.66
Three crop irrigations	0.50	0.59	0.84	1.04	0.37
No irrigation	0.59	0.59	0.81	0.78	0.67

is, in fact, the result of an intricate complex of successive, interdependent biochemical and physical-chemical processes occurring in the soil during and following the time of irrigation." (p. 57).

The data presented do not reveal all the complexity of the process. There is insufficient concrete data to explain the mechanism of increasing alkalinity of soils upon irrigation. We are inclined to explain the increase in alkalinity of solonetz-like dark chestnut soils upon irrigation in our experiments (especially with fall-charging irrigation) by the longer interaction of water and soil. A charging irrigation, given deep in the fall at high rates (1500 m.^{3}/ha. and more) makes possible temporary, but well-developed anaerobic conditions. Inevitably, after excessive wetting the soil, carbon dioxide will accumulate in soil solution which reacts with solid carbonates, silicates, and alumino-silicates of the soil. This causes additional amounts of alkaline earth and alkali carbonates, and also sodium and potassium silicates, to go into solution.

We also observed increasing alkalinity with sudden decreases in soil moisture, which involve increased solution concentration. With one crop irrigation and especially one charging irrigation, increased concentration of soil solution took place amid signs of high alkalinity. We must assume that the deciding factor of alkalization is not the moment of dilution of the original soil solution, but the time after irrigation ceases, during which moisture evaporates and the soil dries somewhat. This leads to an increased solution concentration.

In the Saratov district, with the use of one crop or one charging irrigation, the supply of available moisture in the root zone is completely exhausted or has become very small by the second half of June. With this method of irrigation, it is natural to expect an increase in solution concentration in a period critical for the growth of spring wheat. Practically, as a result of increased alkalinity, agronomic properties of the soil deteriorate, such as: formation of crust, hardening of the plow sole, loss of soil structure, and so forth. The use of fertilizers recommended for agriculture (superphosphate and ammonium nitrate introduced separately or together) avoid alkalization of soil upon irrigation. The introduction of basic fertilizers into the system in the usual doses is not effective. That is, it may not prevent alkalization upon irrigation.

Conclusions

1. In solonetz-like dark chestnut soils of t east bank of the Volga River (Saratov district there is a characteristic accumulation of easi soluble salts at a depth of 70 to 80 cm., whic may be transported to the root zone with in proper methods of irrigation.

2. Fall-charging irrigations are beneficia leaching chlorides and sulfates from the ro zone into lower layers, but undesirable alkalization of the soil solution takes place at the san time. Summer crop irrigations show significantl less alkalization, but they have a weak effect i removing chlorides and sulfates from the roo zone.

3. Charging and crop irrigations cannot con pensate for each other, since their effects on th salt regime of soils are qualitatively different.

4. To maintain a favorable salt regime on irrigated solonetz-like dark chestnut soils of banl areas of the Volga River within the Saratov district, charging irrigations should be combine with crop irrigation. With this method of irrigation there is less danger of increasing alkalinity

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FERTILITY OF VIRGIN AND OLD-CULTIVATED SOILS O NORTHERN KAZAKHSTAN

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THE reclamation of large new land areas sets serious tasks for agricultural science. Problems of increasing and intelligent use of fertile soils require profound and thorough study.

Virgin and old-cultivated soils have been the subject of a vast literature. The most attention to this problem is seen in the works of V. V. Dokuchayev (3), V. E. Kazakov (5), P. A. Kostychev (6), A. A. Izmail'skiy (4), V. R. Vil'yams (2), D. N. Pryanishnikov (8), M. S. Tsyganov (10), V. A. Frantsesson (9), N. V. Orlovskiy (7), A. I. Barayev (1) and others. The majority of these works, however, contain little factual material relating to the soil fertility of northern Kazakhstan. The present paper, based on experimental studies of virgin and old-cultivated soils, aims at filling this gap to some extent.

An important indication of potential soil fertility is provided by data on total humus content, nitrogen, phosphorus, potassium and so forth. Virgin ordinary chernozems are the most favorable soils (Table 1) in this connection. Their humus horizons ($A + B_1$) reach 60 to 70 cm. in thickness and the top half-meter layer contains up to 350 to 400 tons per hectare of humus and 23 to 25 tons per hectare of nitrogen. In southern chernozems (poor in humus) the thickness of the humus horizon falls to 50 to 35 cm. The amount of humus in the half-meter layer is up to 250 to 260 tons per hectare, and of nitrogen up to 10 to 13 tons per hectare. In dark-chestnut soils, which are formed under more arid conditions, the humus decreases and qualitative changes occur which are expressed in a relative increase in the nitrogen content and an increased humus mobility (Table 1).

The total phosphorus content of the arable layer of ordinary virgin chernozems is, according to our data, 0.16 to 0.18%, in southern chernozems 0.12 to 0.16%, and in dark chestnut soils 0.09 to 0.12% of the soil weight. The total potassium contents are 1.07 to 1.80, 1.15 to 1.71 and 1.55 to 1.85%, respectively. No substantial difference in total nitrogen, phosphorus and p tassium content is observed between virgin an old-cultivated soils.

The direct sources of plant nutrients are th available forms of nitrogen, phosphorus and potassium, which comprise a small part of th total amounts present (Table 2).

Table 2 shows that ordinary and souther chernozems and dark chestnut soils differ littl from each other in their easily hydrolyzable nitrogen content. On old-cultivated soils th amount of hydrolyzable nitrogen increases. Thi is associated with the intensification of aerobi and ammonification processes.

The north Kazakhstan soils under consideration, especially the ordinary chernozems, contai available potassium in large quantities. Th amount of available potassium in the old-cultivated soils is smaller than in the virgin lands This is connected with the consumption of potassium by agricultural crops and its subsequen removal at harvest. The amount of availabl phosphorus increases somewhat in the old-cultivated soils. On the whole, the phosphorus content of all the soils is very low and does no exceed 10 mg. per 100 g. of soil. Therefore, i is important in these soils to supplement th easily available forms of phosphorus by applying it in the form of fertilizers and mobilizin its total reserves by means of phosphorobacterin

Easily hydrolyzable nitrogen, although relate to the mobile forms, is not directly taken u by plants. Easily hydrolyzable and other difficultly soluble forms of nitrogen are converte into an available form under the influence o the processes of nitrification and ammonification. The process of nitrogen mobilization i clearly seen from the comparison of the dat on nitrate nitrogen. Samples for analysis wer taken from the area of the Il'ich State Farm Chkalov district, Kokchetav province in Jun 1955.

The data in Table 3 show that there ar practically no nitrates in virgin soils. Therefor spring wheat sown after spring plowing, suffers from nitrogen deficiency in the early stage of its development. With the increase in the processes of ammonification and nitrification, nitrogen nutrition improves. Moreover, it is typical that nitrates in fallow on virgin land accumulate in appreciable amounts only in the top layer of the soil (0 to 10 cm.) and are not found at all in the lower layer (10 to 20 cm.), that is the plowed-in sod. The latter is explained by the fact that the nitrates formed in the plowed-in sod are consumed by molds and by cellulose-decomposing microorganisms, which grow especially intensively in the early stage of decomposition.

The highest amount of nitrates is formed in the fallow of old-cultivated soils, which contain considerably less fresh plant residue.

Virgin land fertility was developed under the influence of continuous action of steppe vegetation on the soils. Perennial steppe vegetation can build up a larger quantity of root residues than annual cultivated plants, as is clear from the data in Table 4.

The amount of organic matter accumulating in the soil depends on the type of soils and the plant cover composition. The largest amount of root residues accumulates in ordinary virgin chernozems under a mixture of grasses, including feather grass, and the smallest amount in dark-chestnut soils. Southern chernozems occupy an intermediate position as regards to root residues.

The root mass weight of sown perennial grasses fluctuates over a wide range and depends on the species of grasses and the length of time of their utilization. Sown grasses accumulate considerably less root mass than virgin land vegetation. The amount of roots and plant residues on old-cultivated soils under annual crops does not exceed 60 centner per hectare. The varying qualitative composition of root residues of perennial and annual vegetation also conditions the varying rate of their decomposition (Table 5).

On virgin land, in 1 year under fallow, about 30% of the root residues decompose; in 2 years about 50%. Full decomposition of root residues on virgin land takes place in the 5th to 6th year after plowing, whereas in old-cultivated lands the decomposition of root residues is completed in one year. This is explained by the fact that the composition of plant residues of virgin soils includes a large amount of half-decomposed old roots. These decompose considerably more slowly after the plowing of virgin land than the fresh plant residues of annual crops on old-cultivated soils. During the cultivation of annual crops decomposition not only of fresh plant residues but also of soil humus occurs. As a result of this the humus content decreases (Table 6).

TABLE 1

Humus and nitrogen content

Soil	Depth, cm.	Humus		Nitrogen, tons/ha.	Water-soluble humus/total humus
		%	Tons/ha.		
Chernozem, ordinary clay loam (Kokchetav province)	0–10	6.81	350	23.4	1:387
	23–33	5.63			1:351
	40–50	4.42			1:294
Chernozem, southern fine clay loam (Pavlodar prov.)	0–14	4.66	258	12.8	1:270
	20–28	3.01			1:231
	30–50	1.77			1:160
Dark chestnut fine clay loam (Aktyubinsk prov.)	0–20	4.31	207	13.5	1:221
	20–40	4.00			1:140
	40–50	1.38			1:09

TABLE 2

Content of available forms of nitrogen, phosphorus and potash in the 0 to 20 cm. layer in mg. per 100/gm. of soil

Soil	Utilization	Hydrolyzable nitrogen	P_2O_5	K_2O
Ordinary chernozem	Virgin land	11.1	4.0	76.3
	Old-cultivated land	17.3	6.0	53.1
Southern chernozem	Virgin land	9.0	2.0	40.0
	Old-cultivated land	15.0	5.0	22.0
Dark chestnut soil	Virgin land	12.7	3.0	22.6
	Old-cultivated land	14.8	4.3	46.2

Organic matter decomposition is linked with the biological activity of soils and, in particular, with microbiological action (Table 7).

The total microorganisms in virgin soil is considerably less than in old-cultivated land. The development of separate groups of microorganisms corresponds exactly to the conditions existing in virgin and old-cultivated soils. In more compacted virgin soils when a large amount of organic matter is present, denitrify-

TABLE 3

Nitrate content (mg. per 1 kg. of soil)

Depth, cm.	Virgin land	Fallow (bare plot in wheat crop)[a]	
		On virgin land	On old-cultivated section
0–10	traces	23.0	11.0
10–20	traces	traces	51.0

[a] The fallow was plowed in June, 1954.

TABLE 4

Amount of root residues in the 0 to 20 cm. layer (centner per hectare)

Soil	Vegetation	Roots
Ordinary chernozem (Kokchetav prov.)	Various grasses including feather grass	278.3
Southern chernozem (Pavlodar prov.)	*Festuca sulcata* and feather grass	251.0
Dark chestnut soil (West Kazakhstan prov.)	Feather grass and *F. sulcata*	233.0
Ordinary chernozem (Kokchetav prov.)	Three-year smooth brome	178.0
Southern chernozem (Pavlodar prov.)	Three-year *Agropyron cristatum*	119.0
Southern chernozem (Kherson prov.)[a]	Winter wheat and rye	57.1
Chestnut soil (South Kazakhstan prov.)	Wheat, barley, millet, chick-pea	18.5

[a] Larin, I. V. 1956. Zemledeliye, No. 1.

TABLE 5

Amount of root residues in the soil (centner per hectare)

Locality of sampling	Virgin land			Old-cultivated land		Percentage of decomposed roots
	Before plowing	After plowing		Spring wheat at harvest	Fallow in same field, after 1 yr.,	
		After 1 year	After 2 years			
'Severnyy Mayak' kolkhoz, Kokchetav province	114.3	80		—	—	30.0
'Pamyat' Il'icha' Sovkhoz, Ruzayev district	233.3	—	125.0	—	—	46.4
Dzerzhinskii Kolkhoz, Aryk-Balyk district	—	—	—	50.0	5.0	90.0

ing and cellulose-decomposing microorganisms are widespread, while in the loose old-cultivated soils aerobic and ammonifying microorganisms are abundant.

TABLE 6

Humus content of virgin and old-cultivated land
the 0 to 20 cm. layer

Province	Type of soil	Utilization	Humus, %
Kokchetav	Ordinary chernozem	Virgin land	6.1
		Old-cultivated land	5.1
Akmolinsk	Ordinary chernozem	Virgin land	7.4
		Old-cultivated land	6.7
Pavlodar	Southern chernozem	Virgin land	4.6
		Old-cultivated land	4.2

TABLE 7

Number of microorganisms in southern chernoze of the Akmolinsk province (in 1000 per gm. of soil), August, 1955. (Data of V. F. Nępomiluyev)

Utilization	Depth, cm.	Total number of micro-organisms		Ammonifiers	Denitrifiers	Cellulose–decomposers
		Aerobic	Anaaerbic			
Virgin land	0–10	5500	220	11	2220	3300
	20–30	6720	1120	224	3360	2240
Old-cultivated land	0–10	28890	1284	3210	107	214
	20–30	3870	129	193	2580	258

Closely connected with the processes of accumulation and decomposition of organic matter are the formation and destruction of soi structure (Table 8).

A characteristic of ordinary chernozem i that aggregates larger than 3 mm. in diamete predominate, while on southern chernozem an dark-chestnut soils aggregates larger than 1 t 0.5 mm. in diameter predominate. In old-cultivated soils the number of water-stable aggregates decrease in ordinary chernozems to 6 to 70%, in southern chernozems to 40 to 50% and in dark chestnut soils to 20 to 25%. Thus the structure of ordinary chernozems is the mos resistant to destruction and that of dark chestnut soil the least resistant, while southern chernozem occupies an intermediate position.

In the pre-revolutionary period, with shallow plowing of virgin lands, it was necessary t harrow repeatedly (10 to 12 times) in order to break up the turf. Destruction of the structure down to the state of old-cultivated land took place very rapidly—in 5 to 6 years (6). At the present time, agricultural production has at its disposal all the means necessary for long-term conservation and maintenance of a better soil structure.

Other hydrophysical soil properties, too—bulk density, porosity, water-holding capacity and permeability—depend to a considerable degree on structure. Our investigations of this revealed fundamental differences between virgin and old-cultivated soils (Tables 9 and 10).

Table 9 shows that bulk density changes according to soil type and cultivation methods. Higher bulk density in the 0 to 20 cm. layer is found in virgin land of southern chernozem and dark-chestnut soils; it is somewhat lower in the virgin soil of ordinary chernozem. The lowest bulk density is observed in old-cultivated soils under spring wheat following deep plowing (plow with mouldboard). At the same time in 1956 under spring wheat after fallow, bulk density increased, which indicates soil compaction by steam plowing. In the 20 to 40 cm. soil layer the bulk density in virgin and old-cultivated areas of ordinary chernozem changes little, but considerably more than in the 0 to 20 cm. layer.

The highest water-holding capacity (62 to 68%) is observed in the 0 to 20 cm. layer with deep autumn plowing of ordinary chernozem and dark chestnut soil. The lowest water-holding capacity is found in virgin areas. In ordinary chernozem virgin soil the water-holding capacity is higher than under spring wheat after the 1956 fallow. The opposite relationship in water-holding capacity is observed on bare fallow plowed in the spring of 1957. The decreased water-holding capacity under wheat in the 1956 fallow is explained by soil compaction which is associated with repeated cultivations and soil pulverization.

Water permeability of soil was determined by a special apparatus constructed by S. S. Shain (Fig. 1). To determine water permeability 3 to 4 replicates of samples with undisturbed structure were collected with a cylinder. The volume of the cylinder was 1000 cm.^{3}, height 20 cm., and cross sectional area of 50 sq. cm. (Fig. 2). Saturation of the soil occurred under water maintained at a constant level of 2 cm. above the soil. After full saturation a calculation of water percolating was made every 15 minutes during the first hour and every 30 minutes during the next 5 hours. The data from the determination of water permeability in the 0 to 20 cm. layer for July 2 to 10, 1957 are given in Table 10.

TABLE 8

Aggregate analysis of virgin and old-cultivated soils in the 0 to 20 cm. layer

Soil	Utilization	Percentage of aggregates of diameters, mm.				
		>3	3–1	1–0.5	0.5–0.25	0.25
Ordinary chernozem (Kokchetav prov.)	Virgin land	54.56	16.08	14.40	1.28	86.32
	Old-cultivated land	16.80	18.20	30.68	3.92	69.60
Southern chernozem (Akmolinsk prov.)	Virgin land	10.10	14.45	31.15	4.50	60.20
	Old-cultivated land	2.25	13.90	12.30	21.10	48.55
Dark chestnut soil (South-Kazakhstan prov.)	Virgin land	1.50	15.80	18.68	7.50	43.48
	Old-cultivated land	—	1.86	5.88	14.08	21.82

In all variants with ordinary chernozem, higher water conductivity is noted as regards both soil saturation and percolation rate. Particularly high water percolation is observed on old-cultivated lands after deep autumn plowing.

The percolation rate of the upper horizons of virgin lands (0 to 20 cm.) is 30 to 65 mm. in the first hour, and on old-cultivated soils after autumn plowing 350 to 460 mm. In the lower 20 to 40 cm. layer the percolation rate is greatly retarded and is 3 mm. on the virgin dark chestnut soils, 15 mm. on virgin soil of ordinary chernozem, and 26 mm. on old-cultivated chernozem. As a result of greater water conductivity in old-cultivated soils, there are conditions of better moistening and leaching out of excess water-soluble salts.

All the above clearly indicates the change in virgin soil fertility with cultivation and the introduction of agricultural crops. These changes have both a positive and a negative character when judged by separate indices. On the whole,

TABLE 9

Bulk density and water capacity of the soils in virgin and old-cultivated lands, July 1–10, 1957

Soil	Utilization	Bulk density		Full water capacity,	
		0–20 cm.	20–40 cm.	0–20 cm.	20–40 cm
Ordinary chernozem, medium clay loam (Kokchetav prov., Ruzayev district)	Virgin land	1.05	1.24	52.13	41.59
	Old-cultivated (spring wheat after autumn plowing)	0.91	1.25	62.27	40.68
Ordinary chernozem, fine clay loam (Kokchetav prov., Aryk-Balyk district)	Virgin land	1.04	1.26	54.66	40.75
	Old-cultivated (spring wheat after fallow, 1956)	1.01	1.24	50.93	40.32
Southern chernozem, fine clay loam (Pavlodar prov., M.-Gor'kov district)	Virgin land	1.17	1.16	45.78	45.88
	Old-cultivated (bare fallow 1957)	1.03	1.24	48.57	40.16
Dark chestnut, fine clay loam (Akmolinsk prov., Yesil district)	Virgin	1.16	1.37	48.75	34.38
	Old-cultivated (spring wheat after deep autumn plowing)	0.89	—	67.92	—

TABLE 10

Water percolation of ordinary chernozem and dark chestnut soil

Soil	Utilization	Amount of water after percolating, cc./hour						Soil moisture content at sampling, %	Amount of water for full soil saturation, cc.	Time of saturation mins.
		1 hr.	2 hr.	3 hr.	4 hr.	5 hr.	6 hr.			
Dark chestnut, fine clay loam (Akmolinsk prov., Yesil district)	Virgin land	156.0	122.0	114.5	90.0	80.5	81	14.1	367	132
	Autumn plowland (old-cultivated)	1740	1543	1451	1426	1372	1332	14.0	436	6
Ordinary chernozem, medium clay loam (Kokchetav prov., Ruzayev dist.)	Virgin land	328	293	280	280	281	265	15.1	361	38
	Autumn plowland (old-cultivated)	2180	1893	1820	1750	1772	1717	13.8	422	4

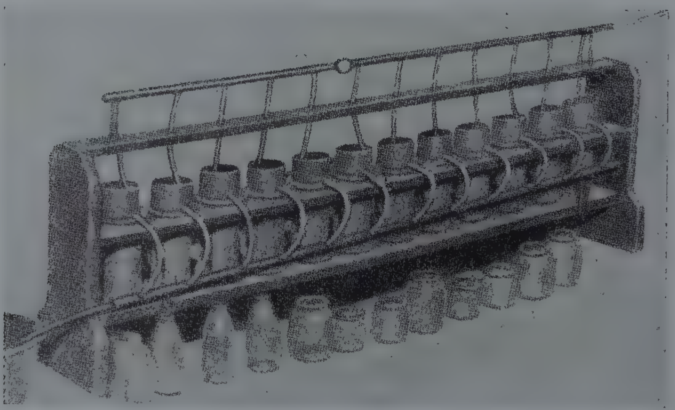

FIG. 1.—S. S. Shain's apparatus for determination of hydro-physical properties of soil.

soil fertility in northern Kazakhstan after plowing of the virgin land is preserved for a long time at a fairly high level. This is shown by the data of yields obtained on the Suvorov State Farm, Pavlodar province, on southern chernozems (Table 11).

It is clear from Table 11 that the yields of spring wheat after fallow on virgin land and on old-cultivated land in 1954—a year of normal precipitation—differ little. With appropriate methods of cultivation it is possible to obtain high yields on old-cultivated soils also. In the dry year 1955 the yield of spring wheat after fallow on old-cultivated soil was half as much as after fallow on virgin land. This is explained by the great weediness of the crops on old-cultivated land.

A count of the weeds in the soil of the Il'ich state farm, Kokchetav province, showed the following: With deep plowing, the surface weedy layer of the virgin land is plowed in and a weed-free layer is brought up. Therefore, the crops are usually free from weeds in the first year of virgin soil utilization. In subsequent years, the number of weed seeds in the soil increases, reaching 23 million seeds per hectare in old-cultivated land. With shallow plowing of virgin land as commonly carried out in the pre-revolutionary period, the weedy layer remained on the surface, and weed infestation increased still more rapidly. This led to a sharp decrease in yields and made it necessary to abandon the old areas to weed fallow and to reclaim new lands.

With improved cultivation and a higher general standard of agriculture, successful weed control becomes possible. Well-timed and sound cultivation of fallows and the use of herbicides form an essential part of agricultural weed control measures.

Conclusions

1. Virgin chernozems and dark-chestnut soils are characterized by high fertility. This is linked with the presence in the upper horizons of a water-stable structure, a large amount of root residues (250–300 centner/ha., in the 0 to 20 cm. layer) and of humus (250 to 350 ton/ha, in the 0 to 50 cm. layer).

2. After plowing of virgin soils, during the process of continuous cultivation of annual agricultural crops, humus content decreases, structure stability is reduced, and weediness increases. In addition to this, microbiological activity is promoted, the amount of available forms of phosphorus and nitrogen rises, and water conductivity increases.

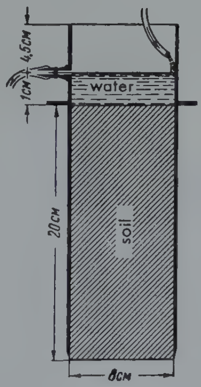

FIG. 2.—Section of metal cylinder for determination of hydro-physical properties of soil.

TABLE 11
Annual yield of spring wheat (centners per hectare)

Field	1954	1955	1956
Fallow after virgin land	21.9	11.6	—
Fallow after old-cultivated land	19.0	6.0	12.9

3. The data of scientific institutes and the experience of collective and state farms indicate that, under suitable methods of rotation cultivation, old-cultivated ordinary and southern chernozem and dark-chestnut soils which were first plowed 25 to 30 years ago insure high yields of agricultural crops under favorable weather conditions.

4. The most important task of agricultural science and practice at the present time is to work out a system of agriculture suitable to actual natural and economic conditions. Such a system should include the correct organization of agricultural land utilization on the basis of the introduction of a coordinated system of field and fodder rotations, a correct system of soil cultivation, a fertilizer policy, planting of protective forest belts, measures to control soil erosion and utilization of the local run-off, snow retention, and the use of chemical methods to

control weeds, pests, and diseases of agricultural crops.

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NUTRIENT ELEMENT DYNAMICS AND BIOLOGICAL ACTIVITY OF PODZOLS FROM THE SOUTHERN FOREST ZONE

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SEASONAL changes in the chemical properties of forest podzols, including the dynamics of nutrient elements, have been thoroughly studied ecently by M. M. Abramova (1), A. K. Alekhina (2), S. A. Kovrigin (3), and K. M. Smirnova (6, 7). But these interesting investigations do not encompass all the important types of orest.

Our data on soils of Mari ASSR supplement the previously mentioned investigations on the dynamics of soil contents of nitrates, nitrites, ammonia, and soluble forms of phosphorus and potassium. They relate not only to one forest type, but also to other geographic regions. Our nvestigations on mineral nutrient dynamics were accompanied by simultaneous study of the biological activity of the soil by measuring the carbon dioxide evolved from the soil under natural conditions. Determination of the soil's carbon dioxide production permits the judgement of the intensity of soil organic matter decomposition and the carbon nutrition of plants.

Determinations of mineral plant nutrient dynamics were carried out for forest litter (A_0) and humus accumulating (A_1) horizons. These are biologically the most active and play the most essential role in furnishing plant nutrient elements.

Mixed soil samples for each horizon were analyzed on the morning after arrival at the laboratory. Nitrates and nitrites were determined according to Rhiem, NH_3 according to Konev (using Nessler's reagent), phosphoric acid according to Kirsanov, and potassium according to Peyve. Biological activity on three to five replicates was determined during the daytime (12 to 14 hours) in the sampling period, according to Shtatnov's method with some of our modifications (8).

In setting up the experiments with biological activity, temperature, soil moisture and reaction were considered. Observations were made during the 1953 growing season in the area of Yoshkar-Ola in Mari ASSR, using virgin forest as well as cultivated soils. Observations were made on loose sandy podzols with dry pine forest (pine-lichen, II age class), forest meadows with broom (*Cytisus ratisbonensis*), and cutover areas with beach grass (*Calamagrostis epigeios*). Later observations were also made on sod medium podzolized coarse clay loams with mixed spruce (60 to 80 years), on the same soil in a series of forest nurseries with 4-year-old pines, and finally on clover meadow in the second year of use. The soil with clover was sod medium podzolized coarse clay loam, lightly cultivated.

Details of meteorological conditions in the 1953 growing season are given in Table 1 from observations of the Yoshkar-Ola meteorological station located closest to our plots.

Temperatures were nearly normal during the warm season of 1953, but the precipitation in spring and early fall was greater than normal, that is, conditions were favorable for development of biological processes.

Figures 1 and 2 show the results of observations on the evolution of carbon dioxide from the soil, ammonia content, available forms of phosphorus and potassium as well as soil moisture.

A brief description of the vegetation and soils on all the plots follows.

Pine-lichen. On dune hills. 10C. II age class, density 1.0; site quality IV–III; soil cover weakly developed: bilberry, lily of the valley, beach grass, lichens, pads of green moss, dead cover prevailing.

Soil—typical sandy podzol on old alluvial sands. Humus content in A_1A_2 horizon, 1.03%; total exchangeable cations, 4.15 me.; hydrolytic acidity, 4.53 me.; cation saturation, 47.82%; pH of water extract, 5.6; humus content in A_1A_2 horizon, 7.4 T/ha.

Dry Pine Forest Meadow. Covered with Cytisus and willow brush. Soil cover of lichens, rarely lily of the valley, beach grass. Litter of leaves and brush of Cytisus.

Soil—typical sandy podzol on old alluvial

TABLE 1
Average monthly air temperature and precipitation (for 20 years and for 1953)[a]

Meteorological item	Months						
	April	May	June	July	August	Sept.	Oct.
Average monthly air temperature, C° (for the period 1926–46)	2.8	11.3	16.3	19.4	17.5	10.4	3.4
Average monthly air temperature in 1953	5.9	11.0	17.8	19.0	18.1	8.6	2.3
Total precipitation, mm. (average for 1926–1946)	34	44	52	63	58	51	57
Total precipitation in 1953, mm.	48	92	52	49	81	74	45

[a] Data of the hydrometeorological service of the Mari ASSR Ministry of Agriculture.

sands. Humus content in A_0A_1 horizon, 4.79%; in A_2 horizon, 1.24%; total exchangeable cations in A_0A_1 horizon, 9.00 me.; hydrolytic acidity, 7.04 me.; cation saturation, 56.20%; pH of water extract, 5.6; supply of humus in A_0A_1 horizon, 9.7 T/ha.

Cut-over Area. Solitary standing pines and birch; rarely Cytisus. Grass cover of moderately thick beach grass. Moderate sod. Humus content in A_1 horizon, 3.34%; total exchangeable cations, 5.98 me.; hydrolytic acidity, 7.80 me.; cation saturation, 43.50%.

Mixed Spruce. 60 to 80 years. Density 0.7; site quality I. Sparse new growth of spruce, oak, linden, birch, aspen; moderately thick underbrush of hazelnut, spindle tree, honeysuckle; poorly developed living soil cover of maianthemum, lily of the valley, pyrola, asarabacca, spring vetch, raspberry, and so forth.

Soil—sod medium-podzolized coarse clay loam, underlain by Permian sands. Humus content in A_1 horizon, 3.13%; total exchangeable cations, 15.70 me.; hydrolytic acidity, 5.40 me.; cation saturation, 74.40%; pH of water extract, 6.3; supply of humus in A_1 horizon, 25.1 T/ha.

Field Plot. Clover in second year. Clover harvested in the middle of July.

Soil—sod medium–podzolized coarse clay loam. Humus content in A_p horizon, 2.76%; total exchangeable cations, 18.40 me.; hydrolytic acidity, 3.86 me.; cation saturation, 82.70%; pH of water extract 6.4; humus content in A_p horizon, 62.2 T/ha.

Forest Nursery. Good stand of four-yea old pines.

Soils—sod medium–podzolized coarse cl loam, underlain by Permian sands.

On dry sandy podzols with pine forest the are two maxima in CO_2 production, ammon and soluble potassium; the first in May June, the second in September or Octobe During July and the first of August—the peri of highest air temperatures and greatest droug —a depression is observed in biological activit ammonia and potassium content. Soluble pho phoric acid is not lower in this period, but some cases is even higher than in the sprin and fall. This is seemingly a result of low biological consumption during this period.

Similar changes can be noted in amounts CO_2, soil moisture, and contents of ammoni and K_2O. But there is no strict correlation be tween them. Some differences among the plot are connected with plant cover features (pin forest, meadow with Cytisus, and cut-over area with beach grass). The largest amount an greatest variation of nutrient elements are ob served in forest litter. The humus horizon i poorer in nutrient elements and less variable In sandy podzols only forest litter shows a hig microbiological activity. This can be seen from the following data: in the A_0 horizon 3.165 mg CO_2 was evolved per hour (average over twelve hour period of observation) per 100 g in the A_1A_2 horizon only 0.180 mg.

Nitrates and nitrites were not observed in the sandy podzols. Traces of nitrate were noted only in May and June. But the absence or insignificant quantity of nitrates is not a sign of the absence or weak development of nitrification. This appearance might result from nitrate assimilation by plants or microorganisms (5, 2). A number of Soviet and foreign soil scientists and microbiologists (5, 11, 12, 13, 14) point out that coniferous forest litter is not favorable for nitrification because of the presence in it of extractable materials. According to our investigations, the biological activity of pine forest litter is considerably less than that of deciduous plantings (10).

An increase in soil acidity is shown in the second half of the growing season (from the end of August to October). This seems to be connected with increased decomposition of par-

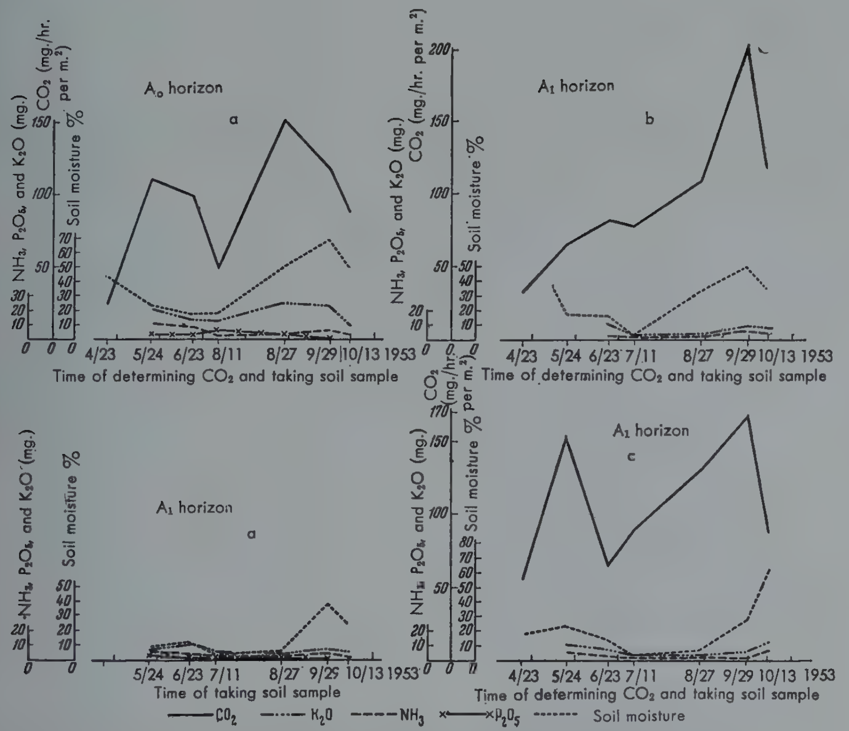

Fig. 1.—Variations in the production of soil carbon dioxide, soil moisture, and contents of NH_3 and soluble P_2O_5 and K_2O in dry pine forest soils. a—Pine-lichen forest; b—Meadow with Cytisus; c—Cut-over area, covered with beach grass.

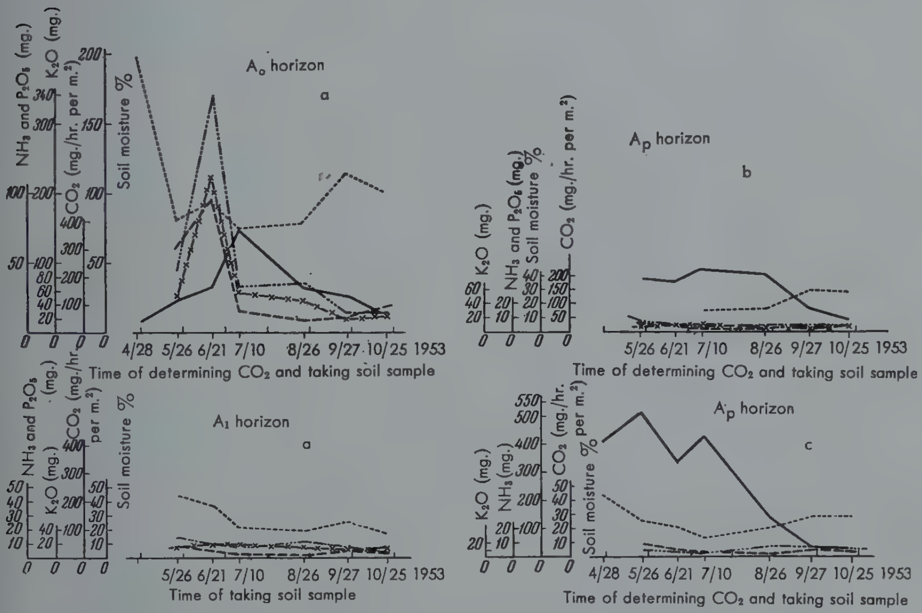

Fig. 2.—Variations in the production of soil carbon dioxide, soil moisture, and contents of NH_3 and soluble P_2O_5 and K_2O in soils with mixed spruce forest and areas formerly with mixed spruce. a—Mixed spruce; b—forest nursery; c—clover meadow. (See Figure 1 for meaning of symbols.)

tially leached litter and increased production of CO_2, which acidifies the solution, in the fall.

On the whole, sandy soils of dry pine forest are characterized by low carbon dioxide production and a very low content of available mineral nutrients. Together with the insufficient water supply, this causes low productivity even of such non-demanding species as pine. It also causes poor reforestation under the conditions of dry pine forest.

On sod clay loam podzols with mixed spruce we see entirely different variations in CO_2, ammonia, P_2O_5, and K_2O (Fig. 2). In the forest litter, sharp increases are observed in ammonia, P_2O_5, K_2O contents in June, and in CO_2 production in July. Afterward there occurs a sharp reduction in mineral nutrient contents until the end of the growing season. Carbon dioxide evolution also decreases in the fall. Sharp separate peaks are clearly distinguishable for ammonia, P_2O_5, and K_2O contents on one side, and CO_2 production on the other. We did not observe such an obvious discrepancy between CO_2 formation and nitrogen, phosphorus, and potassium nutrients in the sandy podzols. It is probably explained by the different rhythms of adsorption and excretion of different materials by the various plant roots in the mixed planting.

The higher soil content of soluble phosphorus and potassium in June and July under mixed spruce is explained by 2 things: 1) reduced absorption of mineral nutrients by roots in connection with decreasing growth of active roots of woody species in the summer, and 2) intensive root excretions of phosphorus and potassium, especially by linden roots (4).

Variations in ammonia and soluble forms of phosphorus and potassium in the humus horizon are less significant and are reminiscent of the variations of these materials in dry sandy podzols with pine forest which has a higher content of ammonia, soluble phosphorus and potassium in the spring and fall (NH_3), and lower in the summer. Comparing the contents of ammonia and soluble phosphorus and potassium in the mixed spruce and pine– lichen forests, it is easily noticed that contents of these elements and their variations in sod medium clay loam podzol with mixed spruce are much greater than in the dry sandy podzol with pine. But nitrates and nitrites were not observed ev in mixed spruce soil. Kovrigin (3) affirmed similar phenomenon for wooded podzol deriv from loess in the Bryansk district.

During the growing season, changes in s moisture, ammonia, soluble P_2O_5 and K_2O the plow layer of sod medium podzolized coa clay loam with the forest nursery and clov meadow are generally similar to changes the humus-accumulating horizon of the mix spruce soil (increases in their contents in t spring and fall). Here, also, there are no n trates or nitrites (Traces of nitrate were not in May and June on both plots.). The cour of CO_2 evolution is quite different: in the nur ery, high CO_2 production is observed in Ju and August, but in the clover area it is in Ma In July the clover was harvested, bringi about a sharp reduction in CO_2 evolution. Th very low content of soluble P_2O_5 in the clov area is explained by systematic harvesting agricultural crops from this area without r plenishing the soil with fertilizers.

The study of dynamics of nutrient elemen and biological activity of the soil has show that, in order to increase forest productivity, is necessary to enrich podzols with availab mineral nutrients and to improve the biologic activity, especially that of sandy podzols. I plantations this may be achieved primarily b regulating the decomposition of forest litter for example, by controlled cutting of forest with natural reforestation, loosening the A_0 horizon, and, in nurseries, by introducing fertilizers For improving biological activity of the soil and carbon and nitrogen nutrition of plants legumes are very important.

Leguminous shrubs may be recommended fo forests. For example, on dry pine forest—broo (*Cytisus ratisbonensis*), and on moist, coheren soils—Siberian acacia (*Caragana arborescens* may be used. Of the grassy plants, lupines an clover are suitable.

Cytisus, Siberian acacia, and perennial lupine according to our investigations (8, 10) improv the biological activity and physical chemica properties of forest podzols.

Conclusions

1. Variations in biological activity and con tents of nitrate, nitrite, ammonia, soluble phos

phorus and potassium were studied simultaneously in podzols under dry pine forest and mixed spruce in the southern forest zone. Soils under pine-lichen forest, open and cut–over areas from such forest, and soils under mixed spruce forest, nurseries and clover from such forest were chosen for observation.

2. The contents of ammonia, soluble phosphorus and potassium, and also the production of soil carbon dioxide, and their variations, were significantly higher in sod medium clay loam podzols under mixed spruce than in sandy podzols under dry pine forest.

3. Nitrates and nitrites were almost never observed, except for traces in May and June on both sandy and clay loam podzols.

4. The greatest peculiarities were found in the production of soil carbon dioxide. Thus, differences in vegetation and soils were shown first of all in the biological activity of the soil. It appears to be the most sensitive indicator of current changes in properties of soil formation and forest vegetation.

5. The forest litter of podzols stands out as the richest in nutrient elements and the most variable.

The humus horizon is biologically less active and lower in available nutrients. But because of the greater thickness of the A_1 horizon and its greater bulk density, the nutrient supply here may be greater than in the A_0 horizon (3). These properties of forest litter require economic interpretation and action to intensifying the biological cycle and increase productivity.

6. In the article, measures are recommended for improving the biological activity and physical-chemical properties of forest podzols.

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SOME RESULTS OF STUDIES OF CERTAIN SOIL FERTILITY ELEMENTS IN FIELD CROP ROTATIONS IN SOUTHERN KUBAN

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In problems concerning the most efficient composition and distribution of crops in rotations, agronomy and practical agriculture have long been guided by the view that there are two periods in the course of a crop rotation: 1) a period of organic material accumulation in the soil and improvement of soil structure owing to perennial grasses and 2) a period of organic material decomposition and breaking down of the soil structure owing to annual crops. The contrast between perennial grasses and annual crops was most clearly described by P. A. Kostychev and further developed by V. R. Vil'yams. Kostychev wrote: "Organic substances in cultivated soils diminish even if present in insignificant amounts or if copiously treated with organic fertilizers, unless perennial grasses are grown in the fields". (2) Elaborating on this statement V. R. Vil'yams concluded that "it is necessary from time to time to interrupt growing annual plants with perennial grasses. (1).

We know, however, that at the end of the past century A. A. Izmail'skiy included annual crops among plants capable of improving the soil structure and its fertility. At the same time we must mention that the viewpoint of Kostychev and Vil'yams—that perennial grasses are the only substances capable of producing accumulation of organic matter in the soil—contradicted their own statement that the soil is the function of vegetation. We also know that Vil'yams recognized the positive role in humus accumulation of chemotrophic bacteria, which are pioneers in soil formation on weathering parent material.

Analyzing the reasons for the inability of annual plants to accumulate humus, T. C. Mal'tsev concluded that it is basically because of the extreme mellowness of the soil from yearly cultivation, which creates aerobic conditions for root residue decomposition of annuals. Thus, Mal'tsev makes no distinction in the biology of annual plants and perennial grasses, considering both equally capable of accumulating humus in the soil.

To create anaerobic conditions in the course of annual plant decomposition, Mal'tsev proposes to produce a compaction in soil. In his opinion, this may be attained if deep annual plowing is replaced by a shallow cultivation of the soil. On the basis of observations and experiments Mal'tsev came to the conclusion that "annual plants may build up the soil structure in accordance with their abilities to develop in compact soils under a certain system of tillage and, consequently, raise its productivity. Instead of annual deep plowing for every sown crop, it is only necessary to surface till the soil (3).

The foregoing statements to the effect that annual plants can develop in a compact soil contradict the centuries-old practice of tilling virgin and mellow soils (to mellow them for raising the annual crop yield) and contradict direct experiments showing the exceptional significance of the mellow state for the development of annual and perennial plants, according to the work of Mosolov (5) and statements by K. A. Timiryazev about the role of deep soil cultivation for raising productivity.

Not so long ago, raising soil productivity was regarded as identical with improving its structure and all agricultural methods were evaluated primarily from their effect on the soil structure. Thus, an early plowing of the sod layer for winter crops was considered harmful since it was assumed that the aerobic conditions thereby created would lead to quick mineralization of the organic material and break down of the soil structure. The same reason was advanced for denying the possibility of distributing cultivated crops over the sod and maximal saturation with such crops of the entire rotation. The problem of beneficial combination and most expedient saturation of field crop rotations with small grain or cultivated technical crops is important. Also important is the problem of the effect of this saturation on the different elements of soil fertility and on the yields of the crops. A solution to the problem of possible maximum saturation of rotations with cultivated crops has become even more urgent because of the need for enlarging areas under corn.

The necessary condition for a more efficient crop distribution in rotations is the acquisition of further factual material about the influence of annual agricultural crops and perennial grasses on soil fertility.

We have adhered to the principle that soil fertility cannot be reduced to a matter of structure alone. No less important are other properties, especially the water regimen and nutrient reserves.

We have studied several conditions characterizing soil fertility: accumulation of plant material in soil under perennial grasses and under annual agricultural crops and qualitative composition of these plant residues; structural analysis and formation of the arable horizon of fields under crop rotation; humus content, total nitrogen content and available nutrients. We also observed changes in water conditions of the arable and subarable horizons.

In the work done between 1953 and 1955 we used permanent experiments with comparative studies of the effectiveness of five different field crop rotations, inaugurated in 1946 by the Soil-Agronomy Station and the Krasnodar Selection Station, outlined and directed by M. G. Chizhevskiy. Two rotations were chosen for the study with the following alternating crops. *Rotation No. 3*—1) first year grasses, 2) second year grasses, 3) spring wheat, 4) winter wheat, 5) sunflower, 6) winter wheat, 7) winter wheat, corn, 9) winter wheat, 10) barley sown wi grasses; *Rotation No. 4*—1) first year grass 2) second year grasses, 3) cotton, 4) wint wheat, 5) castor plant—*Ricinus communis,* winter wheat, 7) sunflower, 8) winter wheat, corn, and 10) barley sown with grasses.

TABLE 1

Quantity of root and stubble residues in the soil under different agricultural crops (the weight of air dried mass in centners per hectare)

Crop	Total root and stubble residues, %	Including	
		Roots	Stubble
Winter wheat	36.8	4.1	32.7
Corn	37.8	21.5	16.3
Sunflower	29.9	10.6	19.3
Ricinus communis	40.3	10.5	29.8
Cotton	23.7	14.8	8.9
First year grass mixture	62.3	44.9	17.4
Second year grass mixture	86.7	54.5	32.2

The No. 3 rotation was 60% filled with sm grain; the perennial grass was used with sma grain; cultivated and small grains were used forerunners of winter wheat. The No. 4 rotatio was 40% filled with cultivated crops; the gra was used under the cultivated technical crops various cultivated technical crops were used preceding crops of winter wheat. The last fiel of these crop rotations had no perennial grass and crops were alternated in time according the cultivated rotation. This allowed a comparative study of the individual elements of so fertility in grass as well as in these cultivate crop rotations.

The soils in these experiments—western cis caucasian leached chernozems—are characterize by great thickness of the humus horizon (A + B up to 160 cm.) and by small humus conten (up to 4%) in the upper horizons, diminishin with depth. With respect to texture they ar fine clay loams.

Soil fertility is known to be inseparable fro the presence of organic substances. This is th most important factor in determining its physicochemical properties. Agronomy and practical agriculture are familiar with several methods o enriching the soil with organic substances, bu plant residues are the most important. In ou experiments, various agricultural crops accumulated the following quantities of root and stubbl residues in the arable soil layer (Table 1).

The greatest amount of the air-dried organi material 86.7 to 117.2 ctr./ha. accumulated unde second year perennial grasses. After one year o growth perennial grasses left 60 to 62 ctr./ha The quantity of plant residues from annual crop was 1.5 to 2.5 times smaller than that fro the perennial grasses of one year's growth. However, even that amount of root and stubble residues which accumulates under annual crop cannot fail to have a positive effect on th physicochemical soil properties. Annual plant and perennial grasses provide energy materia for microbiological soil processes and accumu ate considerable quantities of nutritive substances from the soil.

The analytical data show that the roots of various agricultural plants differ considerably with respect to content of nitrogen and ash elements (Table 2).

In absolute terms, that is, considering the total content of nitrogen, phosphorus, potassium and calcium in organic residues, per hectare, perennial grasses stand out sharply when compared with annual crops. For instance, with root and stubble remains of winter wheat the soil received about 25 kg./ha. of nitrogen, 22 kg./ha. of potassium, 2 kg./ha. of calcium, 5 kg./ha. of phosphorus. As a result of corn root decomposition (without the stubble) the soil receives up to 13 kg./ha. of nitrogen, 8 kg./ha. of calcium and over 42 kg./ha. of potassium. A good deal of potassium—17 to 25 kg./ha.—enters the soil with the roots of the sunflower and *Ricinus*.

In the roots of a perennial grass mixture the nitrogen content exceeds 140 kg./ha., potassium 72, calcium 36, phosphoric acid 20 kg./ha. If the nutrients entering the soil with the perennial grass stubble are taken into account, the amounts given previously will increase more than 1.5 times. Consequently, the nitrogen and ash elements entering the soil with the roots of perennial grasses exceed by far the amounts coming from annual crops. However, even that quantity of nutrient substances left in the soil after the residues of crops decay cannot fail to affect the nutrient conditions of the soil in crop rotation.

The larger quantity of residues of perennial grasses favors the maximum formation of humus (3.86 to 3.88%) and of total nitrogen (0.198 to 0.201%) both in the grass fields themselves and in the fields with crops with sod. The differences in humus and total nitrogen content of the crop rotation fields Nos. 3 and 4 are not great. In the fields where the crops alternated with the cultivated type of crop rotation, the humus content comprised 3.55 to 3.57%, that is, considerably less than in the fields with grass in the rotations. Along with other factors, this also influenced the soil structure.

The quantity of water stable aggregates in soils under perennial grasses is always greater than in soils under other agricultural crops. It is interesting that use of a grass under cultivated technical crops does not adversely affect the soil structure. Thus, in the fall of 1954, in rotating the sod of winter wheat field with cotton, the soil in rotation No. 4 contained 65.7% of water stable aggregates >0.25 mm., while in the field of winter grain following spring wheat in rotation No. 3 the amount was 62.1%.

TABLE 2

Chemical composition of roots of grasses, cereals and technical crops

Crop	Content of absolutely dry material, percent			
	N	P_2O_5	CaO	K_2O
Winter wheat	0.89	0.41	0.49	0.55
Spring wheat	1.00	0.32	0.43	0.72
Corn	0.68	0.18	0.41	2.22
Sunflower	0.58	0.17	0.53	1.92
Ricinus communis	0.92	0.38	0.56	1.68
Cotton	1.14	0.14	0.47	0.73
Sudan grass	1.68	0.39	0.86	0.74
First year alfalfa-ryegrass mixture	1.94	0.36	0.51	1.14
Second year alfalfa-ryegrass mixture	2.08	0.29	0.53	1.05

Ricinus communis in rotation No. 4 exerted a more favorable effect on the soil structure than did the sunflower. Winter wheat produced a particularly weak effect on the structure following winter wheat after the sunflower. This alternation approximates the cultivating type of rotation in its effect on soil structure. Table 3 shows the structural changes (from 1953 to 1955) in this alternating of crops (field No. 119); we cite for comparison the changes in soil structure in cultivated crop rotation with winter grain after winter grain following corn (field No. 105).

TABLE 3

Changes in water stable aggregates >0.25 mm. in diameter in the 0 to 25 cm. layer, percent

Field No.	Alternating crops in fields (1953–1955)	Quantity of water stable aggregates >0.25 mm.					
		1953 Oct. 15	1954			1955	
			May 18	July 11	Oct. 25	May 9	June 21
119	Sunflower, winter wheat, winter wheat	56.4	57.4	59.8	64.2	49.3	54.6
105	Corn, winter wheat, winter wheat	53.6	52.5	55.7	62.8	46.5	54.3
109	Winter wheat, corn, corn, winter wheat	53.1	53.4	58.4	62.5	55.2	58.6
106	Winter wheat, corn, winter wheat	45.6	49.5	50.0	59.5	45.8	54.3

TABLE 4

Changes in available water in the two-meter layer of the soil (0 to 100 and 100 to 200 cm.), millimeters

Crops	Soil depth, cm.	1953				1954			
		June 15	June 30	August 25	Oct. 16	May 3	June 7	August 26	October 15
Sunflower	0–100	145	71	44	64	143	142	20	15
	100–200	89	66	32	35	92	94	17	25
Ricinus communis	0–100	157	127	30	50	136	148	26	26
	100–200	117	96	74	67	85	99	68	68
Corn	0–100	—	—	—	—	145	148	40	26
	100–200	—	—	—	—	99	105	98	45
Second year grass mixture	0–100	120	65	1	40	135	85	20	5
	100–200	101	47	10	11	109	77	19	28

The quantity of water stable aggregates in field No. 109 of the grass field rotation, with winter grain—corn—winter grain as a three year alternation, was considerably higher than in a similar cultivated rotation (field No. 106) although seasonal changes showed the same regularity.

Observations on seasonal soil structure variations in crop rotations have shown that the quantity of water stable aggregates diminished during the winter-spring period, particularly in the upper 0 to 10 cm. horizon. This is because of the rains (which, besides their mechanical action, unfavorably affected physico-chemical stability) because of cultivation, and also lowered temperatures that suppress the microbiological processes. Later, as microbiological activity develops, the decomposition of organic matter accelerates and the quantity of water stable aggregates from the spring to the autumn increases considerably under all the agricultural crops, including the annual ones. For example, in 1954, from the spring to the fall, the quantity of water stable aggregates in the 0 to 25 cm. soil horizon increased under the sunflowers by 11.5%, under winter wheat by 8%, under the corn by 10.4%, under spring wheat over the sod by 13.6%.

Observations on the cultivated horizon structure in crop rotations indicate that under cultivated crops the soil becomes extremely compact toward the end of the growing period, particularly under corn and cotton. In fields where winter wheat followed corn and cotton the soil also had the least general porosity as compared wi winter wheat fields that had other previous crop The same fields also had lower water perme bility.

Another major factor in soil fertility is s moisture. It is known that the moisture stora depends on several things; the amount of pr cipitation, physico-chemical properties of t soil, biological characteristics and cultivati methods.

The soil moisture was determined monthly a depth of up to 2 meters in all fields of t crop rotations. The maximum amount of moi ture in the arable layer was observed in t spring, the minimum in July and August. Th greatest desiccation was under perennial grasse The moisture distribution in the two-meter dept in various crop rotation fields may be seen i Table 4.

Second year perennial grasses use moistu to the full two-meter depth and considerabl dry out the soil. However, our analyses indicat that during years of normal moisture the dryin effect of perennial grasses is compensated fo by fall and winter precipitation during the firs year after plowing. The soil under small grai dried more in the upper one-meter depth. Onl in the field of winter wheat after sunflower wer the deeper layers dried out. As may be see in Table 4, only 17 mm. of available water wa in the 100 to 200 cm. layer after sunflower in th fall of 1954, whereas after all other previous crop there were 68 to 98 mm. This is the result of th more potent drying effect of the sunflower, whic unlike other cultivated crops, dries the soil t the full two-meter depth. Distribution of mois ture under the sunflower in the soil profile i scarcely distinguishable from that under peren nial second year grasses. The drying action o the sunflower on the soil is fully compensate for by the fall and winter precipitation only i the upper one-meter layer.

Our investigations of the soil nutrients in crop rotations showed that the process of nitrificatio proceeded more energetically in the fields of th grass crop rotations than in similar fields o cultivated rotations. Nitrates in the winter whea fields likewise accumulated unevenly, varyin with the previous crops. The dynamics of th nitrate nitrogen in the winter wheat field afte connection with different crops are given in Tabl 5. The reason for the marked difference in nitrifitation between the cultivated rotation and the rotation with grass fields is the lower humus content of the fields under cultivated crop rotations and, possibly, the less mobile forms, for humus is the most important source of nitrogen. No sharp differences could be revealed between the different fields and crop rotations as regards variations in the ammonia form of nitrogen and available forms of phosphoric acid.

In order to evaluate as a whole the effect of any crop rotation on soil fertility we analyzed samples of the soil taken from the last winter wheat fields in all crop rotations (Table 6).

It is evident from Table 6 that according to the basic indicators of fertility, field No. 119 (in rotation No. 3), where, since 1949, grasses, only one cultivated crop, and three small grains were grown, differed little from field No. 115 (in rotation No. 4) where grasses, three cultivated crops and only two small grains were grown. Therefore, a high saturation of the grassfield crop rotations with cultivated crops does not lead to a lowering of soil fertility.

The same pattern is also found in cultivated crop rotation: fertility in the rotation saturated with grain crops scarcely differs from that in a rotation maximally saturated with cultivated crops. However, fertility in the grassfield rotations is greater than in cultivated rotations. This is the result of the more potent action of perennial grasses as compared with annual crops, which we observed also in the nonchernozem zone (6).

TABLE 5

Quantity of nitrates in the 0 to 25 cm. soil layer in a field of winter wheat, mm./kg. of absolutely dry soil

Crop rotation	Previous crop to winter wheat	1954 Sept. 10	May 7, 1955		June 16, 1955	
			Under plants	Clear ground	Under plants	Clear ground
3	Spring wheat	70.6	4.3	61.6	5.0	137.9
4	Cotton	31.4	5.4	20.3	4.3	121.7
3	Sunflower	8.9	6.4	26.1	5.4	80.9
4	*Ricinus communis*	27.5	7.0	20.6	4.8	106.9
3	Winter wheat	50.4	7.9	38.4	5.6	111.3
3	Corn	—	6.1	15.7	5.1	58.3
3	Winter wheat	29.2	4.8	9.4	3.7	53.9
3	Corn	8.2	7.0	6.5	4.0	31.0

Quite high yields were obtained from all agricultural crops in the crop rotations during the years of investigation (Table 7).

The yield of hay from the perennial grasses for the first year was 28 to 40 ctr./ha.; the yield of the second year was more than 1.5 times higher. The yield of spring wheat in our experiments over three years was considerably lower than the yield of winter wheat. The spring wheat with grass cover yielded for the three

TABLE 6

Effect of different crop rotations on soil fertility

Crop rotation	Field No.	Year after perennial grasses	Alternating crops preceding winter wheat	Depth, cm.	Humus, % according to Tyurin	Total nitrogen, % (after Kjeldahl)	P_2O_5, mg. per 100 gm. of soil (after Truo)	Quantity of water stable aggregates, % (after Savvinov)
3	119	fifth	Grasses (1949–1950), one cultivated crop (1953), three small grains (1951, 1952, 1954)	0–10 10–25	3.93 3.88	0.200 0.182	40.4 36.5	49.3
4	115	sixth	Grasses (1948–1949), two small grains (1951–1953), three cultivated crops (1950, 1952, 1954)	0–10 10–25	3.77 3.90	0.192 0.183	40.7 38.5	52.1
Tilled fallow	105		Two cultivated crops (1950, 1953), five small grains (1948, 1949, 1951, 1952, 1954)	0–10 10–25	3.57 3.58	0.183 0.188	46.0 42.4	46.5
Tilled fallow	106		Three small grains (1949, 1951, 1952) four cultivated crops (1948, 1950, 1952, 1954)	0–10 10–25	3.55 3.60	0.190 0.190	41.3 40.4	45.3

TABLE 7
Crop yield in the third (grassfield) crop rotation

Alternating crops	Yield, ctr./ha.			
	1953	1954	1955	Average for the three years
First year grasses	40.0	30.8	37.2	36.0
Second year grasses	65.0	52.4	49.5	55.6
Spring wheat[a]	10.0	15.5	15.4	13.6
Winter wheat	24.4	20.6	26.3	23.8
Sunflower	25.2	20.6	26.8	24.2
Winter wheat	33.7	17.5	20.2	23.8
Winter wheat[a]	26.4	17.6	23.0	22.3
Corn	39.2	37.2	55.9	44.1
Winter wheat	27.6	13.0	19.0	19.9
Barley[a]	16.5	13.9	—	—

[a] These fields received fertilizers.

TABLE 8
Crop yield in grass crop rotation No. 4

Alternating crops	Yield, ctr./ha.			
	1953	1954	1955	Average for the 3 years
First year grasses	33.5	28.8	38.2	33.3
Second year grasses	69.8	46.9	52.7	56.5
Cotton[a]	10.6	18.8	24.8	16.4
Winter wheat	30.2	14.5	24.0	22.9
Ricinus communis	10.6	7.2	12.2	10.9
Winter wheat	34.9	18.9	27.0	26.9
Sunflower	24.9	21.0	26.5	24.1
Winter wheat[a]	27.3	18.8	23.3	23.1
Corn	42.0	36.9	57.2	45.4
Barley[a]	15.8	13.2	—	—

[a] These fields received fertilizers.

TABLE 9
Crop yields in field Nos. 105 and 106 of the cultivated crop rotation

Years	Alternating crops in field No. 105	Yield, ctr./ha.	Alternating crops in field No. 106	Yield, ctr./ha.
1953	Corn	39.2	Winter wheat[a] (after the sunflower)	27.3
1954	Winter wheat	13.0	Corn	36.9
1955	Winter wheat[a]	25.4	Winter wheat	14.9

[a] These fields received fertilizers.

years an average of 13.6 ctr./ha. Winter wheat after the sod layer in the same crop rotation experiments for the same period of years (1953–1955), according to the data of V. S. Kosinskiy, yielded 26.5 ctr./ha. The highest yield of wint wheat in our experiments was obtained in cr rotation No. 4 after *Ricinus*.

In the same series (the fourth year aft the sod was plowed) the yield of winter whe after sunflower in crop rotation No. 3 averag 3.1 ctr./ha. less, for the three year period ar 6.8 ctr./ha. less in 1955.

Examining the separate elements of soil fe tility, we also observed a very favorable con bination in the field of winter wheat that su ceeded *Ricinus*.

The sunflower yields were practically the san on the third year after plowing the sod in rota tion No. 3 and in the fifth year in rotation No. Consequently, in the humid regions of Kuba the inclusion of sunflower within the grassfiel crop rotation as the third or the fifth crop afte plowing of the sod layer does not affect it yield.

Table 9 gives the crop yields in fields No. 10 and 106. There they were alternated with th cultivated rotation without perennial grasses.

Table 9 shows that high yields of winter whea can be obtained in cultivated rotations afte fertilization. However, in our experiments highe yields were obtained in the grass crop rotation after the same preceding crops. (Tables 9 an 7).

The insufficient yield of winter wheat afte corn may be explained by the late harvestin of the corn for seed. There are higher yields i the grass rotations. That and a comparison o some elements of soil fertility in individual cro of the grass rotation with similar crop in th cultivated rotation justify the conclusion tha perennial grasses in the humid zone of Kuba are the best means of increasing fertility an productivity of soils. However, one must no contrast perennial grasses with annual crop in regard to effect on the soil fertility, as wa done until recently. Perennial grasses with th same aerial mass increase fertility more tha annual crops do. But the role of the latter i fairly substantial, as our experimental data hav shown.

Some investigators believe the higher the yiel of an agricultural crop, regardless of the method employed, the higher the soil fertility in th future. This view is based on the fact that plant use less humus for their own growth than the leave in the soil. This opinion is unsound an does not get to the heart of the phenomena. An increase in yield may raise soil productivity, lower it, or leave it unchanged, depending on soil conditions and the technique employed. It is a well known fact that a considerable portion of the organic material produced is diverted in the form of an underground or aerial part. While the carbon and nitrogen contents in the air are almost endless, the amount of nutrients in the soil and the subsoil is limited. It is wrong, therefore, to attribute soil fertility wholly to the carbon contents in the soil. The relationship between the mineral elements needed by plants in different soils varies with the parent material and its genesis. Parent materials differ in total contents and in the form of mineral elements. Therefore, in cultivating plants a varied effect on soil fertility changes depends on soil conditions. In the case of soils with parent material rich in mineral elements, increased yields and greater soil fertility may be brought about without the use of fertilizers. This may be done by making the nutrient elements more available as a result of intensified cultivation or other agrotechnical meliorative procedures. Moreover, as a result of the extraction of mineral elements from parent material by plants, their contents in the soil will increase mainly in the form of organic substances. When the reserve of elements is limited, increased consumption with the growth of yields of agricultural crops and increased diversion of the organic material produced may temporarily lead to a rise in soil fertility. However, later on, owing to diversion of the greater part of the organic substance created, fertility will decline to a greater or lesser extent. Either total exhaustion of elements in the soil and the subsoil or a depletion of individual elements may occur. Therefore, to increase yields of agricultural crops systematically and to raise soil fertility it is necessary in the overwhelming majority of cases to provide nutrients in the form of organic and mineral fertilizers.

The concept of soil as a natural body whose reserve elements are inexhaustible (so that ever larger yields can be obtained without the introduction of fertilizers) is a serious mistake that may harm our country's agriculture. The exhaustion and deterioration of physical properties of various soils from wrong cropping may occur at different times. Long ago K. Marx warned that a temporary rise in soil fertility may, under certain conditions, take place at the expense of exhausting its permanent sources. This is evident from Marx' statement: "Capitalist production, therefore, develops the techniques and combined social processes in such a way that it undermines at the same time the sources of every kind of wealth: the earth and the worker" (4).

Conclusions

1. Root and stubble residues of perennial grasses in the arable soil layer accumulated in the amount of over 60 ctr./ha. in one year and up to 117 ctr./ha. in two years.

From 23 to 40 ctr./ha. of plant residues accumulated under grain and technical crops, which also helped to maintain the organic matter.

2. Perennial grasses, as compared with annual crops, stand out with respect to the total nitrogen, phosphorus, potassium, and calcium content of plant residues per hectare. However, the amount of nutrients contained in residues of annual agricultural crops may also have some positive effect on the nutrients in crop rotation.

3. The amount of water stable aggregates in the soil increases under perennial and annual agricultural crops from the spring to the fall, which shows the exceptional role of the root systems (along with other factors) of all agricultural crops in the processes of structure formation. However, conditions for building up a water stable soil structure are better in fields of perennial grasses than in fields of annual agricultural crops.

4. With respect to individual elements of soil fertility (quantity of humus, nitrate nitrogen, water stable aggregates, water permeability) fields of cultivated rotation are inferior to similar fields in grass crop rotations. Therefore, perennial grasses because of their high yields and importance as fodder, are the best agrotechnical means of raising soil fertility.

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Discussion

CLASSIFICATION OF SOILS TRANSITIONAL FROM MEADOW SOILS TO CHERNOZEMS OF THE FOREST-STEPPE BELT, WEST SIBERIAN LOWLAND

Ye. A. Afanas'yeva and P. U. Bakhtin

IN soil science there has as yet been no clearly developed classification of the soils which constitute links between meadow soils and chernozems. At the same time, a more precise characterization of the properties of the individual "sub-groups" of these soils is of great theoretical interest and is indispensable in practice, especially when working out differentiated farming practices which correspond to soil-climatic conditions.

In the classification of meadow soils and chernozems, consideration is usually given to their morphological structure, chemical composition, texture and physicochemical properties, but the different kinds of relations within these soils are almost totally ignored: those of the water, temperature, salt, gas, nutrient and so forth. Often, investigations are made of incomplete soil profiles without determination of their lower boundaries or consideration of the depth of the water table. The study of the structure of the lower, carbonate-containing part of the profile is indispensable for knowledge of these soils. The soils described here are composed predominantly of two horizons—one humic, the other carbonate—as well as a transitional humic horizon. Ordinary and southern chernozems which have developed on uniform parent material of fine texture, usually also have in the lower part of the profile a salt horizon containing gypsum. In part of this there are easily soluble salts.

Some of the principal characteristics by which chernozem soils are divided into "sub-groups" are the humus content in the upper 10 cm. of soil and the thickness of the humus horizon, as well as the humus content in the upper 50 or 100 cm. In classifying chernozem soils among their different "sub-groups," consideration is also given to such characteristics as restriction or extension of the humus or carbonate horizons, the presence of SiO_2 grains, stains of humus in the transitional and carbonate horizons, the soil structure, and a number of others.

Since chernozem-meadow and meadow-chernozem soils include analogs of almost all the "sub-groups" of steppe[1] chernozems (southern, ordinary, thick, rich, leached, podzolized, solonetz-like and solodized), soil science has until recently made use of the same characteristics for dividing meadow soils into "sub-groups" as were used for dividing steppe chernozems into "sub-groups." Although the morphological structure (habitus) of meadow soils is different from that of chernozems, it is unfortunate that until recently these differences have not been given the importance they deserve. In dividing the steppe chernozems into "sub-groups" no consideration has been given to the water relations. For this reason the meadow soils of forest-steppe and steppe belts have usually been combined with chernozems when they are characterized in descriptions and on large-scale and survey-type soil maps.

Ignoring the soil water relations as characteristics for classification has often led soil scientists

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[1] For present-day steppe chernozems we consider water relations of the non-leaching type to be characteristic.

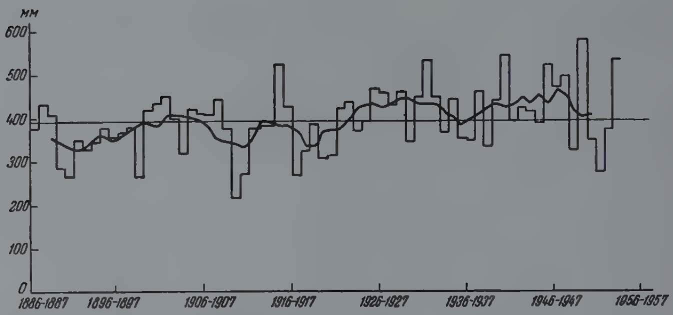

FIG. 1.—Total annual precipitation at Shadrinsk (block outlines) from 1885 to 1955 and its smoothed curve, made by taking 6-year averages.

to assign even chernozem-meadow soils with water relations really associated with the half-bog "sub-group" (to say nothing of meadow-chernozem soils) to the chernozems, that is, to soils of moderate and even of insufficient moisture content. This is, of course, a profound error from both the theoretical and practical standpoints. Living conditions for plants with water relations of the half-bog "sub-group" of chernozem-meadow soils are completely different from those of the steppe chernozems.

For developing a soil classification spanning the categories from meadow soils to chernozems, the area of the collective farm "Zavety Lenina," Shadrinsk district, Kurgansk region, and the fields of the Kurgansk Agricultural Experiment Station, where we conducted the research in the summers of 1955 and 1956, were quite suitable. The collective farm is located on a slightly dissected plain with the water table close to the surface. The soil cover was composed, accordingly, mostly of chernozem-meadow and meadow-chernozem soils and of soils transitional to the chernozems, all showing various degrees of leaching, solonetz-like processes and solodization.

The soil-forming rock is the source of the mantling sandy clays and the fine-clay loams. They are not thick. At a depth of 2 to 3 m. they are usually underlain by sands. The lower part of the profile sometimes fades off into the sand. The fact that the parent material is composed of these components plays an important part in the water relations of the soils. This dual composition has different effects in different soils, depending on the depth of the water table and the thickness of the top layer.

The water and other relations are a measure of the dynamics of those phenomena whose extent and direction are weather-determined unde all physicogeographic conditions. Thus, to gain more or less correct conception of any of th relations, including the water relations, we mus have data from many years of observations including, if possible, wet and dry years—or bette yet, wet and dry periods lasting many years. A analysis of many years of climatic data give a better understanding and estimate of the wate and other relations.

An analysis of the total annual precipitatio from 1885 to 1955 at the Shadrinsk Meteorological Station, 20 km. from our location, shows tha the years during which our research took plac were preceded by a moist period lasting 32 year (Fig. 1). It is conceivable that we are witnessin one of the highest water tables ever caused b climatic fluctuations within the present epoch.

The existence of a considerable rise in th ground water (up to the present time) caused b a prolonged wet period is shown not only by a analysis of the precipitation data for many years but also by the presence of frequently-encountered, recently-swamped forest tracts in whic well-developed stands of birch and aspen ar dead or dying because of excessive moisture.

To characterize the water relations of soils w will use the same indices which A. A. Rode (4 used in his outline as a basis for delineating an characterizing the sub-groups of water relations

The severe climatic conditions of the forest steppe zone of the West Siberian Lowland account for the corresponding hydrothermal soi relations. The sub-groups of water relations w have described do not fit into the outline propose by Rode since Rode's outline was based on dat

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lating chiefly to the European part of the SSR, which has a milder climate. The sub-roups of water relations we have described are upplementary to Rode's 16 sub-groups. To clary the effect of the severe climate on the water lations in this area, we have introduced into the escriptions of the sub-groups the expression with summer thawing," for example: "groundater half-bog with summer thawing."

The soils linking the meadow-chernozem soils ith the chernozems may be divided into four roups according to the depth of the water table nd the specific characteristics of the water relaons.

Steppe Chernozems

The water relations are of the non-leaching ype. The sub-group is designated "steppe, with ummer thawing." The atmosphere is the water ource, and the soil may or may not receive suplementary water from surface runoff. The water able is at a depth of 10 to 15 m. or more. Beeath the soil profile there is a dry layer with a oisture content close to the wilting moisture WM)[2]. There is no internal drainage. The moisure content of the saturated strata in spring usually equal to the least moisture capacity LMC) and does not change from one year to the ext. The depth to which the chernozem is wet hanges in different years depending on the eather. Moisture content higher than the LMC observed immediately after the snow melts or fter abundant rain, but only for a very brief eriod since the gravitational water quickly perolates downward.

During the hot months two periods are disinguished in steppe chernozems according to the legree of moisture of the root zone. In the first alf of the growing period, in the soil stratum which is wet from springtime on, there is water f intermediate availability in the range from MC to PCM (Fig. 2, *A*). In the second half f the growing period the profile of steppe cherozems usually contains moisture which is available only with difficulty, that is, in the range from PCM to WM. This is because the summer rains usually only moisten the upper 10 to 20 cm. of soil. The soils often freeze when the moisture content is low.

Climatic variations occurring in the present epoch do not change the type of steppe chernozem water relations. They affect only the depth to which these soils become wet in spring. In wet years, in the first and second halves of the growing period, there is less difference in the extent of wetting of the root zone of steppe chernozems. The non-leaching type of water relation exists under climatic conditions in which evaporation predominates over precipitation and where the soil-forming parent material in the soil profile has a homogeneous clay or clay loam. When the soil and subsoil are homogeneous from the surface down to the ground water, the lower part of the profile usually contains a salinized stratum which coincides with the lower boundary of the maximum depth of wetting. Then the soils may be solonetz-like to some degree. The lower boundary of the humus horizon usually has tongue-like projections further down. The profile is about 2 m. thick. The humus content of the upper 10 cm. is 6.5 to 8%. The humus horizon is about 50 cm. thick. The humus content in the top half-meter varies from 275 to 325 metric tons per hectare. In the top one-meter layer it is from 340 to 415 metric tons per hectare. The reaction of the upper humus horizon is neutral, or sometimes weakly acid or alkaline.

The maximum diffuse $CaCO_3$ content usually coincides with the layer which is transitional from the humus horizon; as a rule it is not pronounced. Most of the calcium carbonate in the carbonate horizon is in dispersed form. There is usually an interlayer with lime carbonate concretions. Pseudomycelia often occur. This is because the soil often dries out under the snow with the non-leaching type of water relations, resulting in excellent absorption of the snowmelt during thaws. This accounts for the fact that, at the beginning of the growing period, the upper carbonate horizon of steppe chernozems is moist and unfrozen. This allows carbonates from the carbonate horizon to rise to the humus horizon, and in doing so the migration of calcium carbonate takes place chiefly via the paths of roots, forming pseudomycelia in the process. There are practically no

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[2] In the remainder of the text we will designate he wilting moisture by WM, the broken capillary moisture by PCM, the least moisture capacity by MC and full moisture capacity by FMC.—Auhors' footnote. [The initials "KV" are also used but not explained); they probably stand for "kaillyarnaya vlagoyemkost'"—capillary moisture apacity—and I have used CMC for this.—Transator]

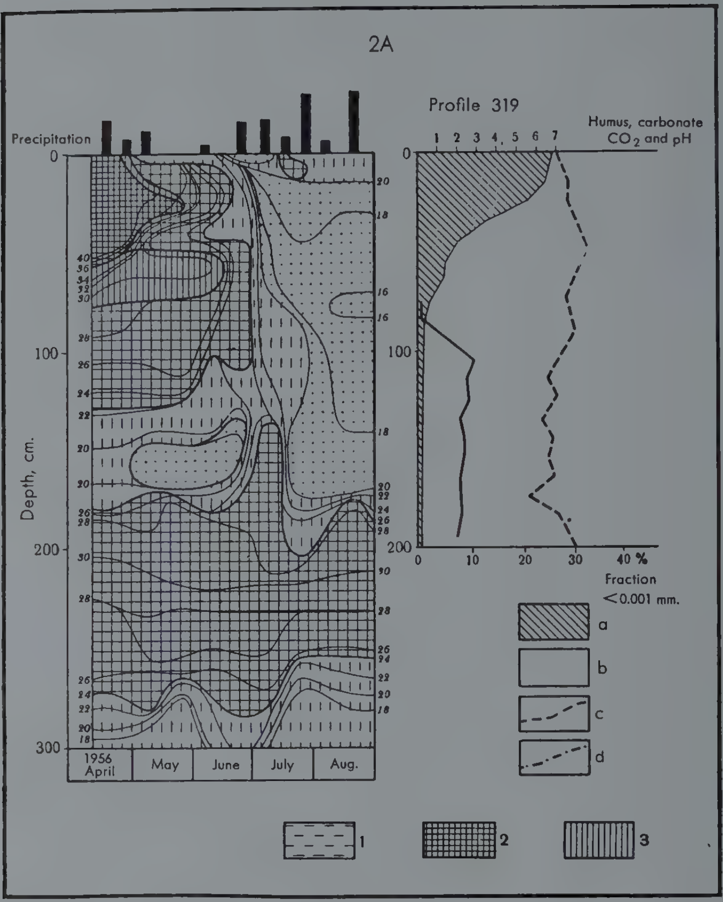

FIG. 2A and 2B.—Soil moisture as percent by volume and in soil moisture categories. A—Plot 22: Steppe chernozem; a sowing of spring wheat; B—Plot 18: Meadow-steppe chernozem with mixed herbs and grasses. The symbols apply to both Figs. 2 and 3. 1—Ground water; 2—readily available moisture, sometimes transitional to excess moisture, between FMC and LMC; 3—optimal LMC (of intermediate availability); 4—optimal moisture of intermediate availability between LMC and PCM; 5—non-readily available moisture between PCM and WM; 6—unavailable moisture from WM and below. a—Humus in percent; b—carbonate CO_2 in percent; c—percentage content of soil fraction less than 0.001 mm. in diameter; d—pH of water suspension.

chemical reduction processes in steppe chernozems.

Meadow-Steppe Chernozems

Water relations are of the leaching type, periodically leached group, of the sub-group "forest-steppe with summer thawing." The water supply is atmospheric, with or without a supplementary supply from the surface runoff. The ground water is at a depth of 5 to 6 m. or deeper. The grou is wet clear through in fall or spring but not ev year. Sometimes this occurs in the summer. Th is periodic drainage of water within the soil, of in the lower profile. There is periodic moisten of the lower profile and sometimes of the hur horizon with perched capillary moisture. The is frozen down to 1.5 to 2 m.; it thaws in the m dle of June. Climatic extremes strongly affect

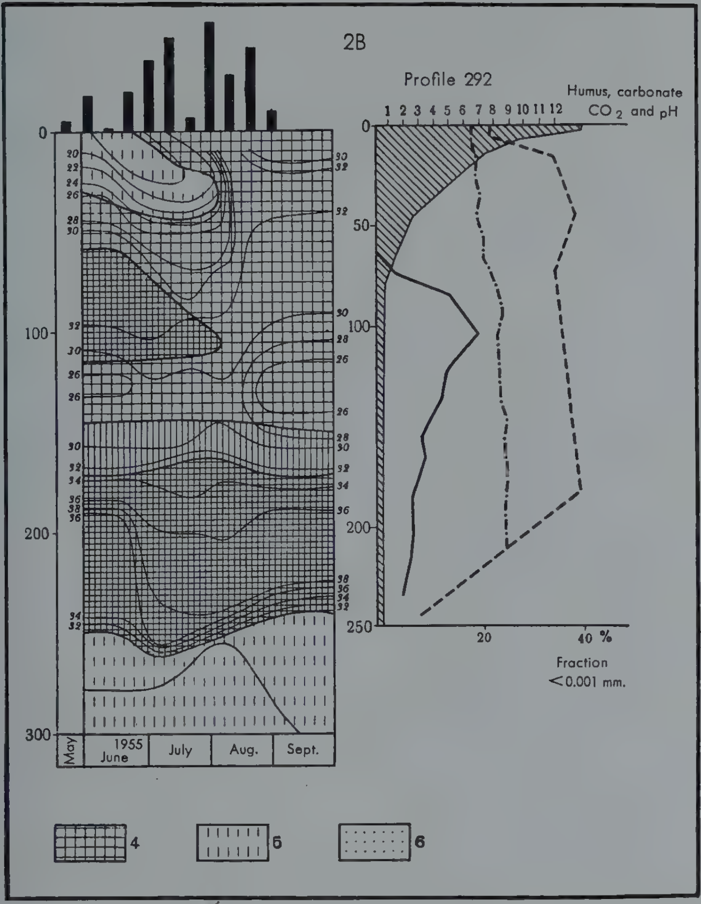

FIG. 2B

water relations of meadow-steppe chernozems. During wet periods lasting a number of years meadow-steppe chernozems are leached all the way through. In this process, owing to the phenomenon of perched capillary moisture in the soil profile, the limits of the moisture fluctuations during the growing period are made much broader (from CMC [capillary moisture capacity] or sometimes from FMC to MC). In other words, during wet periods lasting a number of years, the water relations of meadow-steppe chernozems approach those of meadow soils. This is shown by the fact that the amount of water stored in the soil in spring exceeds the LMC. During the entire growing period there is gravitational perched capillary water in the carbonate horizon (Fig. 2, *B*). Drainage within the soil takes place, chiefly in the lower profile. The difference in the degree of moistening of the root zone in the first and second half of the growing period is evened out. Reduction processes take place at times during different periods of the warm half of the year. During dry periods lasting a number of years, the water relations of meadow-steppe chernozems approach those characteristic of steppe chernozems. In the designation of this "sub-group" of soils we wish to emphasize the changeable nature of the water relations.

For the occurrence of water relations of the periodic leaching type with perched capillary moisture in the lower part of the profile of the meadow-steppe chernozems, more is required than an appropriate climate in which total annual precipitation is, on the average; equal to evaporation. It is also necessary that the subsoil be composed of two components in which the upper layer of the soil-forming parent material is composed of clays or clay loams, while the lower consists of medium or coarse clay loams, sandy loams or sands. In the forest-steppe the best conditions for chernozem formation and for the degree of manifestation of this subtype of water relations occur when the limit of soil deposit extends as deep as 2 to 2.5 m. (that is, to the lower margin of the soil profile), in which a good effect is produced by an abrupt change in the type of deposits. With a change in deposits at a depth of about 3 m. or more, no noticeable accumulation of perched capillary moisture takes place in the soil profile. It need not be thought that the dual composition of the soil-forming parent material is a local or rare phenomenon. It is widespread in nature among parent materials of different origin. Parent material of a composition similar to that observed in the districts where our research took place is described by N. D. Pustovoytov for the Zeya-Bureya plain (3). The same composition occurs in the forest-steppe belt of the Central Ussuri plateau (1) and in a number of other places. Gravitational water may appear in the carbonate horizon of meadow-steppe chernozems also when the subsoil is of uniform texture, but only when a frozen layer of later-thawing soil is present in the lower soil profile.

The periodic appearance of perched capillary moisture in the carbonate horizon of meadow-steppe chernozems has important genetic consequences and plays a large part in the formation of the forest-steppe soil cover.

The carbonate horizon of meadow-steppe chernozems has a better moisture supply than steppe chernozems and, thus, higher fertility and a greater biological cycle. The accumulation of capillary moisture in the lower profile of meadow-steppe chernozems inhibits the leaching of these soils and intensifies the upward migration to the root zone of soil solution containing a relatively high concentration of calcium bicarbonate. These soils have the largest humus contents in the top 1 m. layer and, if we judge the degree of intensity of the chernozem-forming process only by the accumulation of humus, these soils are "the most chernozemic." The profile is about 2.5 m. thick. The humus horizon is about 50 cm. thick. T humus content of the upper 10 cm. layer is abo 14%. The humus content in the upper half-met layer is about 300 metric tons per hectare. As rule, tongue-like projections are found in t lower edge of the humus horizon. The hum horizon has an acid reaction, but the surface lay is the most acid.

There are no easily soluble salts in the profi of meadow-steppe chernozems because their w ter relations are of the periodic leaching ty and the water table is relatively deep. There no solonetz-like formation in these soils. Thu we may assume that during moist periods lasti a number of years, mineralized ground wat does not reach the profile of these soils. T cinnamon-brown to pale yellow carbonate hor zon of these soils has a friable consistency an an unstable prismatic structure. Most of th $CaCO_3$ is in a diffused condition. The maximu content of calcium carbonate in the diffuse state is clearly delineated in the upper carbonat horizon by its color and density. This is confirmed by analyses (Fig. 2, *B*). There are man pseudomycelia. Rarely, there are scattered loos lime concretions which usually do not form subhorizon of "white eye" spots. Weak signs o gleying appear only in the lowest part of th profile above the boundary between the soil an underlying sands.

Meadow-Chernozem Soils

These belong to the leaching type of water relations, periodically leaching group, sub-grou meadow-forest steppe with summer thawing. Th water table is at a depth of 3 to 4 m. and is usually below the lower edge of the soil profile. Th water supply is from the ground water and th atmosphere, with or without supplementary water from the surface runoff. The soil is wet clea through almost every spring and fall and sometimes in summer. There is constant drainage chiefly in the lower profile. The lower profile i constantly moist with ground water (capillar or film-capillary moisture). The ground wate rises in June after the soil thaws; the water tabl sinks in summer because of the reduction in so suction and rises in the fall. In the upper half o the profile the moisture varies from CMC an FMC to PCM and rarely to WM. In the lowe half of the profile the moisture varies betwee FMC or CMC and PCM. The soil freezes to depth of 1.5 to 2 m. and thaws, as a rule, in th first half of June.

When the water table is high, the two-component composition of the soil-forming parent material has less effect on the water relations of meadow-chernozem soils, at least during the years of our observations, since in this case the water table lies within the upper layer of covering clay which is more or less homogeneous in texture. In places where meadow-chernozem soils have now developed, the water table evidently goes down to about 5 to 6 m. during the dry cycle of years. At that time such soils assume the water relations characteristic of the chernozems of meadow-steppe soils.

The alternating character of the water relations of meadow-chernozem soils causes the salt relations also to be changeable. When the ground water rises to its present-day limits the profile of meadow-chernozem soils is invaded by water which is saline, although only weakly so; but when the water table descends, the salts are leached and this causes solonetz-like formation in these soils.

In meadow-chernozem soils, just as in chernozem-meadow soils, the upward attraction of moisture from the saline ground water takes place chiefly in the first half of growing seasons which are preceded by a dry fall, that is, in the presence of dry frost which allows complete wetting of the soils by the water in spring. Fluctuations in the depth of the water table caused by cyclic climatic changes exert the greatest influence on the periodic changes in the water relations and other soil processes, especially in the meadow-chernozem soils. In the dry climatic cycles the water relations of meadow-chernozem soils assume more of the characteristics of steppe chernozems because in dry climatic cycles, dry years tend to recur significantly more often than do years with average moisture and far more often than do wet years (see Fig. 1). For this reason perched capillary moisture apparently appears only rarely in the lower profile. The probability of the appearance of perched capillary moisture in the lower carbonate horizon also decreases as a result of the relatively great thickness of the clay deposit (Fig. 3, *A*). During wet climatic cycles like those of the years of our observations, a capillary fringe occurs in the lower part of the profile of meadow-chernozem soils. From this fringe saline ground water is drawn up into the upper part of the profile.

These soils are about 2.5 m. thick. The upper 10 cm. layer of meadow-chernozem soils contains from 9 to 11% of humus, while the humus horizon is about 60 cm. thick. The humus content in the upper half-meter layer varies from 360 to 470 metric tons per hectare. The humus horizon has an acid reaction, an irregular lower boundary, and, usually, a gleyed carbonate horizon. The distribution of calcium carbonate in the diffused state in the carbonate horizon is variable because of the great changeability of the water relations of this kind of soil. There are few pseudomycelia. Lime concretions are distributed irregularly throughout the solum. There is no definite subhorizon of "white eye" spots. There are usually hard $CaCO_3$ concretions ("zhuravchiki") in the lower half of the carbonate horizon.

Chernozem–Meadow Soils

The water table is at a depth of 170 to 270 cm. and periodically appears in the soil profile (Fig. 3, *B*). The upper boundary of the capillary fringe is always within the profile, but sometimes rises to the surface. The water relations are of the leaching type; the sub-group is ground-water half-bog with summer thawing. The soil obtains its water from ground water and from the atmosphere, which may or may not be supplemented with surface runoff. The soil is entirely wet in fall or spring and sometimes in summer. There is constant drainage from the soil. Capillary moisture is always obtained from the ground water. The ground water falls in the summer from lack of moisture and rises in June after thaw and after abundant rains at the end of summer and in fall. The moisture in the upper half of the profile varies between FMC and WM, and in the lower half from FMC to LMC, or somewhat lower. The soils freeze to a depth of 1.5 to 2 m. and thaw somewhat earlier than soils which are similar but drier.

Climatic cycles within the present epoch are manifested to a smaller degree on the water relations of chernozem-meadow soils (with the water table at about 2 m.) than on the meadow-chernozem soils (with the water table at about 4 m.). Since with the half-bog sub-group of water relations, plants use up more water from the capillary fringe and thus lower the water table during moist periods, so that the range of water table fluctuation is decreased in going from the moist to the dry climatic cycles.

The total thickness of the soil profile is about 120 cm., if we consider as the lower boundary the depth at which the $CaCO_3$ content becomes con-

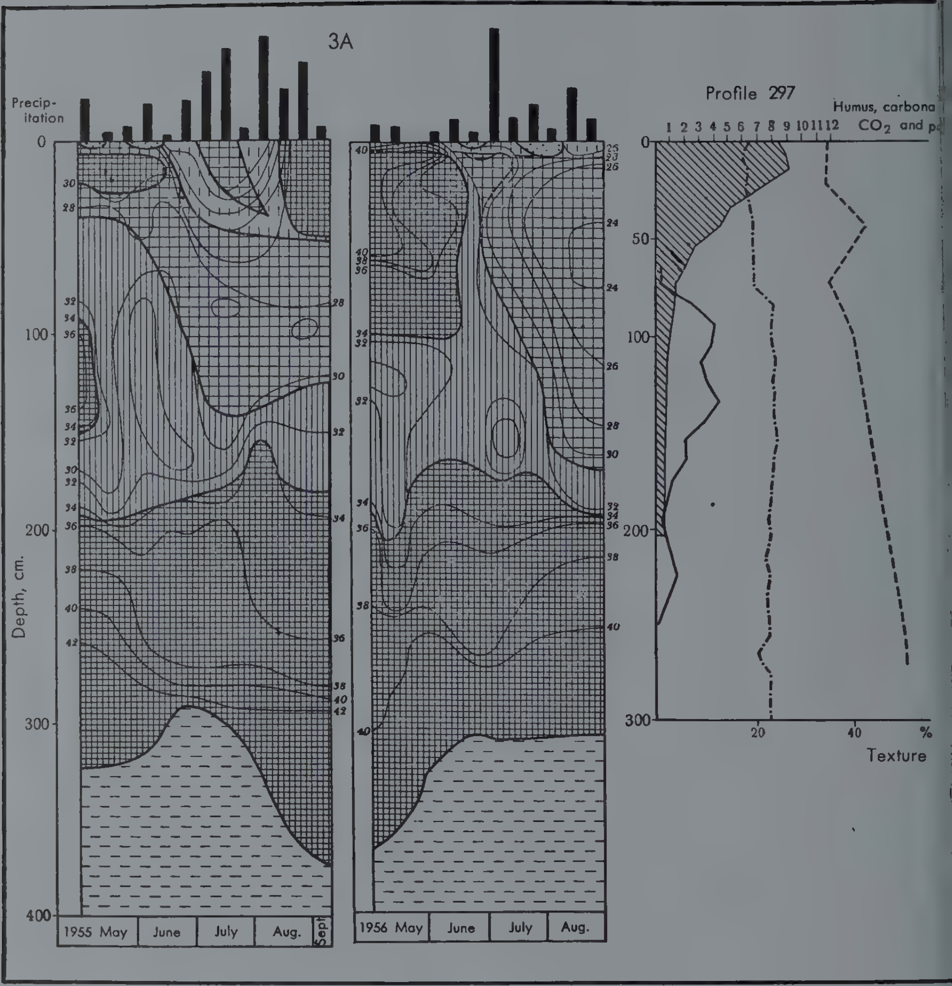

FIG. 3A and 3B.—Soil moisture as percent by volume and in soil moisture categories. A—Plot 3: meadow-chernozem soil under a sowing of spring wheat; B—Plot 17: chernozem-meadow soil; vegetation consists of meadow and hayfield types. Symbols are the same as those in Fig. 2.

stant. The humus horizon is about 5 cm. thick. The humus content near the surface is 11% and higher. The humus content in the upper half-meter layer is from 250 to 325 metric tons per hectare.

The basic characteristics of the kinds of soils distinguished here are compared in Table 1. The principal difference among these soil categories is the depth of the water table, but there are also differences in the type and subtype of water relations. The total thickness of the soil profile i noticeably different with each category. The mos shallow soil profile is characteristic of chernozem-meadow soils. The humus horizon is about a thick as in all the other categories of soils described.

The steppe chernozems are distinguished b the smallest humus content in the surface soi layer, while the meadow-steppe chernozems hav a top 10 cm. layer which is richest in humus. Th

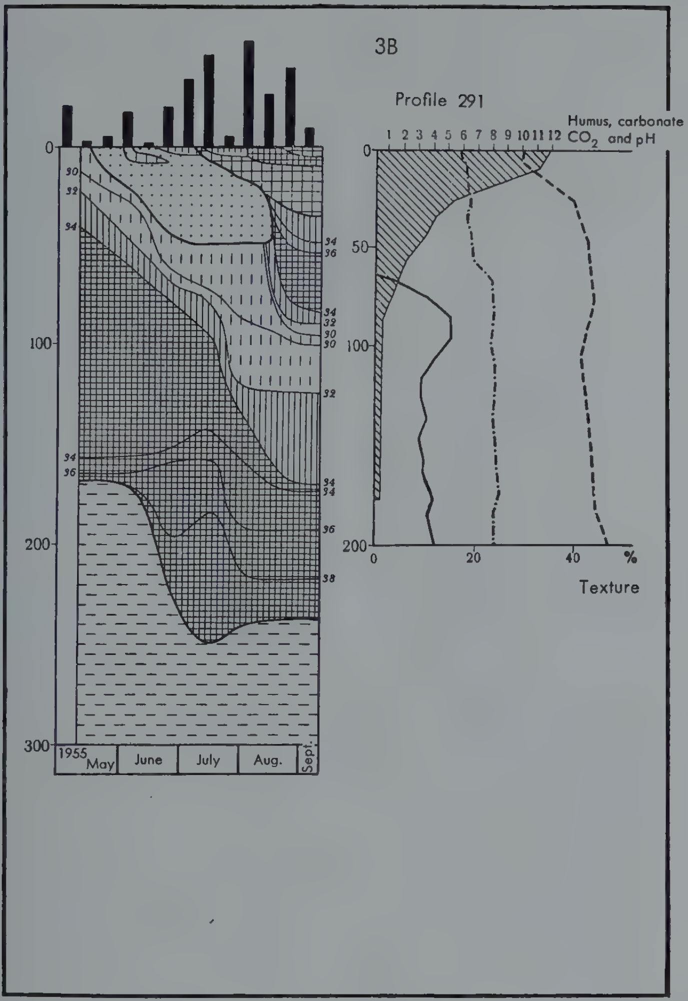

FIG. 3B

carbonate horizon of the steppe chernozems has a vague maximum at its upper boundary. Sometimes there are pseudomycelia. There are no signs of gleying in the carbonate horizon. There is usually a pronounced subhorizon containing "white eye" spots. In the meadow-steppe chernozems there is usually a sharply pronounced maximum accumulation of carbonate salts at the upper boundary of the carbonate horizon. As a rule there is no subhorizon of "white eye" spots. There are often abundant pseudomycelia. Sometimes slight gleying is observed, but usually only in the lower carbonate horizon.

There are neither easily soluble salts nor solonetz-like formation in the profile of meadow-steppe chernozems. In meadow-chernozem soils the distribution of carbonate salts in the carbonate horizon is usually varied. A subhorizon with "white eye" spots is usually not evident. The carbonate horizon is always gleyed, especially in its lower part. There are hard, silicified $CaCO_3$ concretions ("zhuravki"). In the upper carbonate horizon of chernozem-meadow soils there is a pronounced maximum of carbonate salts. The entire carbonate horizon is usually gleyed, especially in the lower part. Throughout the horizon there are

TABLE 1

Basic indices of soil groups

Soils	Depth of water table, m.	Types and subtypes of water relations	Mean total thickness of profile, cm.	Thickness of humus horizon, cm.	Humus content of top 10 cm. layer, %	Humus content in top 50 cm. layer, metric tons/ha.	Easily soluble salts	Extent of solonetz formation	Extent of gleying	Reaction of humus horizon	Depth to which frozen, m.	Date of thaw
Chernozem-steppe	10 or more	Non-leaching type, steppe sub-group with summer thaw	200	50–60	6.5–8	275–325	At lower boundary of soil if soil is of uniform composition	Sometimes solonetz-like	Not gleyed	Neutral or weakly acid or alkaline	1.5 to 2	Middle to end of June
Meadow-steppe chernozems	5 to 6 or more	Leaching type, periodic leaching group, sub-group forest steppe with summer thawing	250	50	12–14	300 325	Lacking	None	Slight, only at lower boundary of soil profile	Acid	1.5 to 2	Same
Meadow-chernozem soils	3 to 4	Leaching type, periodic leaching group, sub-group meadow-forest steppe with summer thawing	250	60	9–11	350–450	Present in small quantities	Often solonetz-like	Carbonate horizon strongly gleyed	Acid	1.5 to 2	Middle of June
Chernozem-meadow soils	1.7 to 2.7	Leaching type, sub-group ground water-half bog with summer thaw	120-150	55	10–11	250-325	Same	Sometimes solonetz-like	Same	Acid	1.5 to 2	Beginning of June

friable and hard silicified $CaCO_3$ concretions. There is no subhorizon with "white eye" spots.

Up to the present time, the four categories of meadow-steppe soils surveyed here have, for the most part, been combined with the chernozems in descriptions and on both large-scale and survey-type soil maps. The chernozem-meadow and meadow-chernozem soils of the "Zavety Lenina" Collective Farm are represented on the 1:50,000 and 1:1,000,000 soil maps as leached, solonetzlike and solodized chernozems, which are then subdivided according to the thickness of the humus horizon. However, the meadow soils are shown on the 1:50,000 map by a narrow belt along the talus slopes (2). On the 1:1,000,000 soil map the chernozem-meadow soils are shown only as spots, while in the district described here they occupy the areas between rivers and gullies, that is, they have developed on surfaces where "zonal" soils are usually located.

In the sub-group soils described here, from meadow soils to meadow-steppe chernozems, the two-component composition of the parent material and the relatively great depth to which they freeze strongly complicate their water relation and often lend them the characteristics of meadow formation, even when the water table is deep. In other bioclimatic zones and provinces and where there is a layer of parent material made up of only one component, the chernozem-meadow and meadow-chernozem soils are distinguished from the meadow-steppe and steppe chernozems by other, evidently more pronounced characteristics; not only by the morphological structure of the profile but by the water relations and other properties.

The depth of the water table gives a direct indication for dividing these soil groups into subgroups according to their water relations. When working in the field careful attention must be paid to the analysis of the soil profile structure, with special attention devoted to the structure of the carbonate horizon, the presence or absence of gleying there, and also to the distribution of carbonate salts in the carbonate horizon and to the kind of lime inclusions.

A clear delimitation between chernozem-meadow and meadow-chernozem soils on the one hand and chernozem meadow-steppe and chernozem steppe soils on the other, both for descriptions and in mapping, is urgently needed, primarily for practical purposes. Different properties like those possessed by chernozem-meadow soils with the half-bog group of water relations and by steppe chernozems—soils of moderate or insufficient moisture—must be considered in selecting crops to be grown and in developing farm practices. Classifying chernozem-meadow and meadow-chernozem soils as chernozems may sometimes lead to irrigated farming on soils of the meadow group in the forest-steppe belt (where the ground water is 2 to 4 m. below the surface) and to intensive fall irrigation. This is not only undesirable but may even be harmful, since these soils are wet clear through to the ground water during the period from fall to spring.

Chernozem-meadow and meadow-chernozem soils are widely distributed in the forest-steppe belt of the West Siberian Lowland and in Eastern Siberia, and also in the European USSR. They often occupy watershed plains to which "zonal" soils are indigenous. When we consider that a considerable part of the lands of the forest-steppe belt have been plowed up and are now under crops, we can understand the importance of the classification of these soils.

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GENUS OF SOD-FOREST SOILS ON RESIDUAL-ALLUVIAL TRAPS

O. V. Makeyev and N. A. Nogina

THE "genus" of soils is a recently proposed taxonomic unit. According to the definition accepted by the first Plenary Session of the Commission on Nomenclature, Taxonomy and Classification of Soils, Academy of Sciences, USSR (7), the soil group is a "group of soils of one sub-group the specific qualitative characteristics of which are caused by local conditions, for example the soil-forming parent material (including the chemical action of the ground water), the previous history of the development of the soil, and so forth." Although we unconditionally support the introduction of this new taxonomic unit, we believe that the definition should be made somewhat more precise. The lack of clarity of the present definition leads to a very arbitrary interpretation of "genus" and of the principles by which the term is delineated when the concept is used.

We believe that the basis for the delineation of soils into a special genus should consist only of those unique characteristics of a soil which are caused by all the specific characteristics of the soil-forming parent material. There must be agreement on the degree and nature of development of these specific characteristics, since the influence of the parent material may be manifested to a varying degree, from delimiting a soil type to constituting an independent great soil group. Distinguishing a great soil group requires the presence of a unique combination of genetic soil horizons which are characteristic only of this particular great soil group. The soil genus should have the same set of differential soil horizons as the great soil group (and subgroup), but it should have, in addition, certain unique traits with respect both to chemical action and to morphology.

The specific characteristics used to determine the genus should be made more precise, otherwise the number of genera will be at least synonymous with the number of soil-forming parent materials.

It seems to us that the previous history of soil development should be refined when delineating genera only when a sharp change in t soil formation conditions have led to the form tion of a new soil profile on soil which has a ready been formed and which then becomes t parent material for the new soil. The charact of the new soil horizons will have unique trai caused by specific characteristics of the previo soil.

We should eliminate from the present form the definition of "genus" the abstract referen to the influence of local conditions and th vagueness in specifying them ("and so forth" because this can lead to an excessively broad an subjective interpretation of genus. The definitio of genus might be expressed as follows:

The genus is a category of soils of a singl sub-group which has not only a combination c horizons characteristic of the great soil grou but also specific qualitative characteristics bot with respect to chemical activity and morphology. These are due to the nature of the soil forming parent material (including the chemica activity of the ground water and the propertie of the parent material appearing as a result o the previous developmental history of this particular soil).

As revised in the light of the previous remarks, the genus acquires a greater geneti specificity and is delimited from the soil type which itself is also delineated, in reality, according to characteristics attributable to the soil forming parent-material. The number of genera in a great soil group should not be very larg by these standards. For example, according t data presently available, it is expedient to distinguish three genera of soils among the sod-forest soils (a sub-group): 1. Sod-forest soils developed on basic rock; 2. Sod-forest soils developed on basic rock rich in sesquioxides; 3 Sod-forest soils developed on basic rock with a high magnesium content.

A very important problem is posed by the nomenclature of genera whose designations are to become a component part of the designation for the particular soil. If we use a color to desigate the great soil group and the description of he soil process for the sub-group, then for the designation of the genus it is expedient to use hose unique properties of the parent material which caused specific properties to appear in he soil. Thus, in the example we have selected, he designations might sound like these: ordinary sod-forest soils, iron-bearing sod-forest oils and magnesium-bearing sod-forest soils.

When genera are delineated, each of them should receive an appropriate genetic characterization. As an example, we will give the characterization of sod-forest soils on residual-alluvial[1] basic rock containing a high concentration of sesquioxides (traps). We propose to delineate hese soils as an independent genus of iron-bearing sod-forest soils.

We have observed sod-forest soils on residual traps on the southern pine-larch taiga of Sibera, where the mean annual temperature is about -1°C. and the mean annual precipitation about 00 mm. Although the climatic conditions are ess suitable for podzol formation throughout the entire Central Siberian taiga-forest zone than hey are on the taiga of the European USSR because there is less than complete wetting of he soil), with certain combinations of factors, podzolic soil formation (chiefly as sod-podzolic oils) is widespread in the area under consideration. These soils are usually lacking only on basic rock. This was noted even by the first soil cientists who investigated this area. D. A. Dranitsyn (1) called these soils "cryptopodzolic." A description of soils on traps is also found in the work of I. A. Shul'ga (8). They were also investigated by V. F. Petrov (5, 6), O. V. Makeyev 2, 3) and N. A. Nogina (4).

Rocks of trap formations occupy enormous areas of the Central Siberian plateau, totaling about a million square kilometers. Among the rocks of this formation are found dolerites, basalts, diabases, and others. Their mineralogical composition is given by the following data:

Diabase from the district of the town of Bratsk: The sample consists of fairly fresh rock having medium-sized grains and an ophitic structure with plagioclase predominating in the form of elongated crystals of labradorite. Between these there is a pyroxene (augite) associated with the deposition of ore (magnetite). In places the pyroxene is severely cracked, and the cracks have filled up with chlorite. Inclusions, consisting of crystalline needles of apatite, are observed within the plagioclase. The quantitative mineral composition of the sample is plagioclase 50%, pyroxene 40%, magnetite 7%, chlorite 2.5%, and apatite 0.5%. A similar composition is found in a sample of trap from the district of the town of Nizhneudinsk (Voznesenskaya mountain): plagioclase 58.6%, augite 22.3%, olivine 12.6%, ore minerals 2.7%, chlorite 2.1%, serpentine 1.6%. According to V. A. Unksov (1934) the average total composition of traps is SiO_2 48.22%, TiO_2 1.84%, Al_2O_3 15.17%, Cr_2O_3 0.025%, Fe_2O_3 2.03%, FeO 11.19%, MnO 0.105%, MgO 6.21%, CaO 10.07%, Na_2O 2.35%, K_2O 0.62%, and P_2O_5 0.23%.

It is extremely characteristic of the total composition of traps that the preponderant part of the iron present is in reduced form.

Residual-alluvial traps may be found in depths up to 2 m., but more often the deposits are 70 to 100 cm. thick. The parent materials contain many tiny, rounded, slightly weathered particles of native rock (sometimes as much as 70 to 80% of them) and the texture of the fine earths is coarse (Table 1). The reaction is neutral, or almost neutral. There is a relatively large amount

TABLE 1

Physicochemical properties of soils in the initial stage of development on residual trap

Profile No.	pH		Humus as % of oven-dry soil (Tyurin's method)	Adsorbed cations (in NH_4Cl extract) in me.[4] per 100 gm. of oven-dry soil			$\frac{Ca}{Mg}$	% of total	
	Salt	Water		Ca	Mg	Total		Ca	Mg
47a (Nogina)	6.0	—	16.1	58.4	9.2	67.6	6.3	86	14
50a (Nogina)	6.0	—	10.8	82.3	14.9	97.2	5.5	85	15

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[1] "Alluvial" is used here in the very restricted ense of weathered material removed and redeposited by temporary, weak currents of water (rain, nowmelt) under the force of gravity. (See V. A. Nosin and B. F. Petrov, Glava III. Metodika i ekhnika pochvennoy s"yemki (Chapter 3. Methods and techniques of soil surveys in the ield), in the symposium Pochvennaya s"yemka (The Soil Survey), I. V. Tyurin et al., eds., Pochvennyy Inst. im. V. V. Dokuchayeva, Izdatel'stvo Akad. Nauk SSSR, Moscow, 1959, p. 57).—Translator.

of exchangeable calcium and magnesium in the parent material. If we consider that they are adsorbed by the very small amount of clay fraction present, we may conclude either that it has a very high adsorption capacity or that not all the calcium and magnesium which is determined as exchangeable is, in reality, actually exchangeable. Evidently both explanations are true. If we calculate the adsorption capacity of the clay fraction of the residual trap, it appears to consist of unrealistic values of the order of 600 to 800 me. per 100 gm. of material. Nogina determined the exchangeable cations by the Gedroits method (displacement by NH_4Cl) of a 0.25 to 1.0 mm. fraction obtained by grinding up trap pebbles in a marble mortar. This showed the content of "exchangeable" calcium to be 14 me. per 100 gm. of this fraction, while the "exchangeable" magnesium was 9 me. per 100 gm. of the fraction. It can be assumed that in this analysis, a part of the calcium and magnesium silicates which had been displaced from a primary-mineral lattice loosened by weathering were included in the "exchangeable" calcium and magnesium. In other soil-forming parent materials, including the dense residual and alluvial rocks of the Central Urals, granites and serpentines), such a phenomenon has not been observed. At the same time we cannot deny the importance of the genuinely high adsorption capacity of the clay fraction in which minerals of the montmorillonite group must occur. In particular, the clay fraction of the residual material of profile 7C (2) contains up to 50% of these minerals. In addition to these circumstances, it may be assumed that the adsorption capacity of the clay fraction is somewhat increased in the preparation for particle size analysis by N. A. Kachinskiy's method. Complete dispersion of parent material rich in sesquioxides is not attained.

Residual traps contain a relatively small amount of silicon dioxide (usually less than 50%), but much iron, aluminum, calcium and magnesium. The largest amount of CaO, which is close to the amount contained in the rock, is noted in the earlier stages of formation of the residual material.

Soils formed on the material described previously have a number of specific traits which are most sharply manifested at the intermediate stages of their development and which are gradually smoothed out as the soils are subjected to the podzol-forming process.

The first stage in the formation of these soi amounts to the covering of a solid slab of tra by an organogenic layer consisting of slightly d composed residues of lichens, mosses and gras vegetation forming a dense tangle with gra roots. This "felt mat" has a cinnamon-brow to brown hue and reaches a thickness of 3 5 cm. It is usually very dry. As the organogen layer becomes thicker it begins to differentiat In its lower part, a dark layer is formed whic shows a considerable degree of decomposition the organic matter and an admixture of miner particles. This layer can be included in horizo A_0A_1 or even A_1.

As seen from Table 1, a slightly acid reactio and a very high adsorption capacity are evider in these soils from the very first stages. Thus, i profile 50a the adsorption capacity is consic erably higher, despite its lower concentration c humus. We attribute this to the degree of organi matter decomposition. In the adsorbing comple there is a predominance of calcium ions whic thus acquire relative mobility from the firs phase of the weathering of traps under fores zone conditions. Further, as the stratum of fin earths increases, horizons B and BC becom differentiated. The profile of soils developed o residual traps takes on the following morpho logical appearance:

Profile 47H. Site 12 km. southwest of th town of Bratsk. The summit is formed from trap intrusion. Elevation, 645 m. Slope wit northern exposure slanting at about 10°. Oc casionally, isolated dwarf larch and pine trees Undergrowth contains spirea and *Rosa* spp. Th herbaceous soil cover consists of grasses, bed straw, asters, astragalus, and, in stony areas various saxifrages.

A_1 O to 12 cm. Dark-gray with cinnamon-brownis tinge; sandy, coarse clay loam, almost sand loam. Gradual transition to lower-lying horizor
AB 12 to 20 cm. Dark-gray, but the cinnamon brownish tinge is stronger than in horizon A_1 Many inclusions consisting of round pieces o trap. Coarse clay loam. Noticeable transition t lower-lying horizon.
B_1 20 to 34 cm. Yellowish-brown (ocher-colored sandy loam; angular pieces of trap from 20 to 20 mm. make up about 50% of the volume of th horizon. Transition to horizon B is gradual.
B_2 34 to 51 cm. Brownish-yellow (rusty-ocherous sandy loam. Peds larger than 1 mm. make u more than half the volume of the horizon. Tran sition clear.
BC 51 to 74 cm. Distinguished from the precedin

by a somewhat darker color and a higher content of angular stones.

elow 74 cm. there is some weathered material ner than 1 mm. but only in cracks between ieces of trap.

As seen from this description, the soil which as developed on residual traps does not show ny signs of podzolization even when there is a hick layer of fine earths. Sometimes in profiles ith a similar habitus small carbonate incrustaions on the rock fragments are encountered at epths of 80 to 100 cm. or more. Here the fine arths do not effervesce (see profile 420).

The accumulation of small particles in the surace horizons, as a result of weathering, is charcteristic of the soils being described (Table). We are inclined to explain the relatively mall content of the 0.01 to 0.005 mm. fraction y the instability of the primary minerals of this ock under chemical and biological weathering. When the rock has been subjected to sufficiently trong mechanical disintegration it rapidly falls part. This process is then followed by accumulaion in the surface layer of clay minerals which re the basis for the clay fraction. The relatively igh loss under treatment with HCl is notable. We consider that this is related to the high conentration of iron and aluminum in the rock. The luminum is partially freed on weathering and oats the mineral particles with a film of hydrated xides. These lend a yellowish-ocherous tinge to he entire soil profile.

Let us now consider the total composition of hese soils (Table 3). We have data on two proles at our disposal. The first, profile 47, is ormed on a shallower and less weathered stratum f residual material, that is, it might represent n earlier stage of development of this soil genus. Notable in both sections is the high content of ron and the low content of silicate. In profile 7 the SiO_2 content increases with depth. Hower, it is difficult to say whether it is the result f the accumulation of other components in these orizons. The latter is the more probable alernative, since a loss of SiO_2 of this order of nagnitude from the surface horizons is compensated by subproportional "accumulations" of ach of the other components. In any case, in he two surface horizons, the loss is made up rincipally by iron.

The accumulation of iron in the surface horizons may be attributed to the fall and winter novement of solutions to the surface and also to the biogenic production of iron. The migration of iron to the surface horizons is evidently made possible both by climatic conditions and the high content of the reduced form of iron in the rock. In any case, the nature of the distribution of SiO_2 and R_2O_3 along the profile provides an adequate basis for the assertion that there is no podzolization here. Even the alkaline earth cations do not reveal a clear picture of loss from the surface horizons.

TABLE 2

Texture of sod-forest soils which have developed on residual traps (as percent of oven-dry soil)

Profile No.	Depth, cm.	Separates, mm.							Loss on HCl treatment
		1.00–0.25	0.25 –0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001		
							Without H_2O_2 treatment	After H_2O_2 treatment	
47H	0–12	17.8	34.1	16.6	4.3	13.5	10.2	8.2	3.6
	12–20	21.1	37.0	14.7	4.0	12.5	8.4	7.8	2.4
	20–24	25.4	36.0	12.3	3.4	10.5	6.6	5.6	2.8
	38–46	30.6	34.5	13.9	3.5	11.3	2.9	1.9	3.4
	70–75	50.8	24.7	9.1	1.5	7.7	3.1	2.5	3.2
50H	1–7	12.8	37.0	16.8	4.6	12.5	13.1	11.3	3.2
	12–18	21.8	35.6	16.1	4.3	7.6	12.2	8.8	2.4
	25–35	23.8	36.3	14.5	2.7	9.6	10.5	—	2.6
	85–91	42.0	34.3	10.5	2.5	3.3	4.1	—	3.0
420M	1–4	11.5	37.2	16.1	5.5	8.3	21.4	—	6.9
	4–12	13.4	40.5	15.2	3.7	4.8	22.4	—	3.8
	12–20	14.2	38.9	14.3	4.0	7.5	21.4	—	3.8
	30–40	27.5	44.4	12.3	3.3	5.8	6.7	—	3.6
	82–92	31.8	41.7	13.5	4.3	3.7	5.0	—	4.8

Profile 420 shows the opposite picture with respect to SiO_2 and R_2O_3 content. The silicate accumulates in the surface horizon, while iron tends to be removed. Separate determinations of the reduced and oxidized forms of iron showed that in the C horizon the reduced form was predominant (9.3% FeO, 5.19% Fe_2O_3), while in the B horizon the opposite picture exists (BC 30 to 40 cm., FeO 6.5%, Fe_2O_3 8.6%).

The relative increase in concentration of silicate in the surface horizons in this case may be related fundamentally to the vigorous removal of calcium. For this reason it cannot be considered a characteristic of podzolization, even if the first indications of podzolization have already appeared, judged by iron distribution. It should be noted here that in the first stages of podzolization's development in this genus of soils, it is unique, because when primary minerals with

TABLE 3

Total composition of sod-forest soil developed on residual traps, as percent of ignited soil

Profile No.	Depth, cm.	Hygroscopic water, %	Loss on ignition	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	CaO	MgO	MnO	Na_2O	K_2O	SO_3	Total	S Fe
47H	0–12	3.75	11.1	46.69	39.03	24.78	14.78	—	—	7.75	4.32	—	—	—	—	99.79	
	12–20	3.17	5.6	47.14	39.52	24.96	14.56	—	—	7.69	4.60	—	—	—	—	98.95	
	20–24	2.88	4.1	47.25	38.53	23.55	14.98	—	—	8.02	4.86	—	—	—	—	98.66	
	38–46	3.10	3.6	48.05	38.63	20.99	17.65	—	—	7.56	4.56	—	—	—	—	98.78	
	70–75	3.13	3.9	48.29	38.17	23.46	14.71	—	—	7.07	5.35	—	—	—	—	98.88	
420M	0–4	3.77	13.4	51.10	31.62	14.76	16.86	2.25	0.10	8.91	3.91	0.68	2.27	1.01	traces	101.02	9
	4–12	3.95	5.5	52.56	31.91	14.84	17.07	1.38	not det'd.	7.55	4.09	not det'd.	—	—	—	97.49	9
	12–20	3.47	4.6	52.50	31.86	14.87	16.99	1.38		7.62	4.30		—	—	—	97.66	9
	30–40	2.27	3.1	47.78	32.24	15.85	16.39	2.46	0.09	9.83	4.66	0.74	2.62	0.86	traces	100.40	7
	89–92	1.87	2.0	49.86	31.95	16.24	15.71	1.52	not det'd.	9.42	4.86	not det'd.	—	—	—	97.58	8
	102–112	0.75	1.7	46.88	31.39	15.52	15.87	2.36	0.08	10.36	4.32	0.44	2.87	1.33	traces	99.03	8
Total composition of clay fraction																	
47H	0–12	7.09	27.8	38.72	54.80	29.96	24.84	—	—	1.11	4.25	—	—	—	—	98.86	
	12–20	7.95	20.0	40.84	54.07	28.85	25.62	—	—	1.00	3.33	—	—	—	—	99.24	
	16–24	7.72	17.4	42.38	52.87	26.91	25.96	—	—	0.14	4.36	—	—	—	—	99.83	
	38–46	6.92	14.8	45.57	50.89	20.56	30.33	—	—	0.14	2.92	—	—	—	—	99.52	
	70–75	7.78	13.0	44.39	49.85	28.71	21.14	—	—	0.14	4.98	—	—	—	—	98.54	

a high iron content become weathered, not all the iron can combine with the aluminum-iron-silicate complex of the secondary clay minerals. The remaining iron either enters into the composition of the organic iron compounds or is found in the form of free sesquioxides. They coat the soil particles, but when the medium is acidified, or when reducing conditions occur, they dissolve and are removed from the surface horizons and, to a certain extent, from all of the strata. Thus, the loss of iron from the surface horizons may not be accompanied by the destruction of secondary aluminum-iron-silicate minerals. Because of the nature of this process it would be more correct not to identify the removal of iron with podzol formation.

We recall that Dranitsyn (1) noted that in residual traps the iron occurs in two forms which differ in their movement capability: the less mobile is represented by silicates and the mobile moiety "which separates out with weathering in the form of hydrates of Fe_2O_3, gives a rusty color to the coarse particles and an ocher color to the finer material."

The total composition of the clay fraction isolated from profile 47H gave the same general picture of oxide distribution by horizons as did the total composition of the soil as a whole. It seems to us that this is evidence that the direction of the soil-forming processes during the enti course of this soil formation was fairly unifor It is notable that the content of sesquioxides the total composition of the clay fraction e ceeds the silicate content. Data from the therm analysis of the clay fraction of profile 47 showe that ferrous minerals predominant among tl secondary clay minerals become more abunda in the surface horizons of the soil, where, addition to these, amorphous substances, ev dently Fe_2O_3, were also observed.[2]

A characterization of the physicochemic properties of the soils described is given in Tab 4. As the pH determinations showed, the surfa horizons of these soils have a slightly acid r action, while the lower horizons are neutral, nearly so. The acidity of the surface horizons creases in proportion to the extent of weatherir of the mineral substrate, that is, to the decrea in concentration of the primary minerals (s profile 420M, which was judged to be mo strongly weathered because of the texture ar the clay content of the profile).

The humus content of the soils described vari

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[2] The thermal analysis was carried out in tl Laboratory of Soil Mineralogy of the Soil Institu of the Academy of Sciences of the USSR under tl direction of Prof. N. I. Gorbunov, to whom tl author extends his thanks.

TABLE 4

Physicochemical characteristics of sod-forest soils developed on Siberian residual traps

ofile No.	Depth, cm.	pH		Humus as % of oven-dry soil (Tyurin's method)	Adsorbed cations (Gedroits method) in me. per 100 gm. of oven-dry soil				$\frac{Ca}{Mg}$	Ca as % of total	Content of fraction 0.001 mm., %	"Adsorption capacity" of 100 gm. of clay in me.
		Salt	Water		Ca	Mg	Total	H				
47 H	0–12	6.0	6.3	8.7	32.0	5.5	37.5	—	5.8	83	0.2	367
	12–20	5.7	6.4	4.1	21.8	6.1	27.9	—	3.7	78	8.4	330
	20–24	5.2	6.2	1.3	18.9	5.3	24.2	—	3.6	78	6.6	366
	38–46	—	6.2	0.9	17.6	6.0	23.6	—	2.9	74	2.9	814
	70–75	5.6	6.9	—	16.2	6.5	22.7	—	2.5	71	3.1	732
50 H	0–1	—	6.9	13.5	24.7	8.9	33.6	0.9	2.7	67	—	—
	1–7	—	6.8	6.4	15.8	7.4	23.2	0.8	2.1	68	13.1	183
	12–18	—	6.6	2.2	12.9	6.7	19.6	0.2	1.9	60	12.2	164
	25–35	—	6.7	1.4	16.2	9.5	25.7	—	1.7	63	10.5	224
	85–91	—	6.8	—	17.8	8.4	26.2	—	2.1	68	4.1	640
420 M	1–4	4.1	5.2	3.6	34.0	8.5	42.5	2.0[a]	4.0	80	21.4	200
	4–12	5.2	6.5	2.4	—	—	—	1.1[a]	—	—	—	—
	12–20	5.0	6.5	0.9	17.0	7.9	24.9	0.2[a]	2.1	68	21.4	110
	30–40	5.0	7.2	0.4	13.0	5.5	18.5	—	2.3	42	6.7	275
	82–92	5.1	7.2	0.1	12.8	4.1	16.9	—	3.1	75	5.0	338

[a] Exchanged H + Al (by Sokolov's method)

nsiderably: in the profile of the most deeply eathered residual material the humus content as lower. It is highly probable that this is a neral tendency of the soils of this great soil oup. The humus decreases very gradually with epth. The unrealistically high value for the "ad- rption capacity" is notable. Our evaluation this phenomenon has already been given above the characterization of the soil-forming rock. e believe that because a decrease in the value the "adsorption capacity" parallels an in- ease in the extent of weathering of the mineral bstrate, the conception previously expressed is nfirmed.

The further development of sod-forest soils on aps in the taiga zone leads to the appearance them of the signs of podzolization, which we assify as the third development stage. This age is reflected in profile 7C (2).

Profile 7C. Nizhneudinsk district, Irkutsk gion. The flat summit of a long rise consisting trap. Vegetation: pine forest. Underbrush ightly developed; consists of Dahurian rhodo- endron and spirea. In the bushy layer there is owberry. The grasses consists of *Calamagrostis dans*, *Maianthemum* spp., meadow rue, and *ypripedium* spp. There are no mosses.

There is no HCl effervescence anywhere in e entire 150 cm. profile.

$_1$ 0 to 5 cm. Dark gray medium clay loam with a fairly firm blocky-granular structure. Noticeable grains of SiO_2. Transition abrupt.

A_2 5 to 12 cm. Brownish light gray coarse clay loam with a granular-blocky structure less firm than in A_1. Considerable content of SiO_2 grains. Transition noticeable.

B_1 12 to 22 cm. Light brown medium clay loam. Firm nutty-blocky structure. Grains of SiO_2. Somewhat compacted. Inclusions of angular rock. Transition noticeable.

B_2 22 to 43 cm. Brown coarse clay loam. Indistinct nutty structure. Many angular rocks. Transition noticeable.

C_1 43 to 64 cm. Yellowish brown. Consists almost entirely of angular rock with sandy loam.

C_2 64 to 150 cm. Solid residual weathered trap and angular stones; sandy loam in small amounts, stained yellow-brown (rusty ocher).

In this profile, horizon A_2 stands out distinctly though it does not yet have the structure and coloration of podzolic soils.

The distribution of particles of "physical clay" (less than 0.01 mm. in diameter) and especially of true clay along the profile reflects the action of the podzolic process (Table 5), but this applies only to the upper soil profile. In the soil as a whole, as compared to the parent material, the accumulation of clay particles is clearly observed. What is lost from the eluvial and gained in the illuvial horizons is the finest (clay) fraction. All the remaining particles, with the exception of medium and coarse sand, accumulate to varying degrees in the surface horizons. But in these horizons there is a sixfold decrease in the content of coarse and medium sand (0.25 to 1 mm.) as compared to the parent material. In the

TABLE 5

Texture of sod-forest podzolized soils on residual traps

Profile No.	Depth, cm.	Size of fraction, mm.							Loss on treatment
		1.00–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	<0.01	
		As percent of oven-dry soil							
7C	0–5	9.1	44.3	16.4	4.6	7.7	17.9	30.2	4.3
	5–12	9.2	42.4	19.4	4.6	7.9	16.5	29.0	3.1
	12–22	10.2	38.6	17.2	3.8	6.1	24.1	34.0	4.2
	30–40	21.0	42.1	16.0	2.4	3.9	14.6	20.9	5.8
	120–130	56.8	18.1	9.0	4.5	2.0	9.6	16.1	4.9

TABLE 6

Total composition of sod-forest podzolized soil on residual traps (profile 7C)[a]

Depth, cm.	Hygroscopic water	Loss on ignition	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	CaO	MgO	MnO	Na_2O	K_2O	SO_3	Total	Si / Fe
	As % of oven-dry soil		As percent of ignited soil													
0–5	2.25	7.83	64.49	24.18	6.70	17.42	1.17	0.24	3.43	2.68	0.36	1.24	1.70	0.48	99.91	2
5–12	1.86	3.41	65.80	24.08	8.68	15.40	1.12	0.20	2.69	1.20	0.28	2.99	2.05	0.24	100.65	2
15–22	2.78	3.10	63.82	26.91	8.45	18.46	1.26	0.08	2.87	1.53	0.20	1.33	2.10	0.27	100.37	2
30–40	2.88	3.82	52.46	35.70	16.30	19.40	1.42	0.29	4.46	4.56	0.15	1.53	1.35	0.24	102.16	9
120–130	2.39	2.88	48.03	38.41	18.41	20.00	1.23	0.16	4.03	4.86	0.14	1.98	2.07	0.22	101.11	6
Rock	—	1.78	38.12	29.27	15.01	14.26	1.79	0.16	9.68	7.76	—	—	—	—	101.30	
Total composition of clay fraction																
0–5	6.64	20.68	44.46	44.32	17.85	26.47	0.84	—	2.70	4.14	0.48	0.72	1.66	0.42	99.94	6
5–12	7.46	12.38	45.32	45.03	17.82	27.21	0.83	—	2.02	3.85	0.32	0.50	1.24	0.41	100.04	6
30–40	8.36	10.97	46.77	45.39	17.45	27.94	0.76	—	1.60	3.69	0.11	0.30	1.17	0.26	100.05	7
120–130	11.28	9.25	46.94	39.75	20.66	18.09	0.22	—	2.52	9.02	0.42	0.27	0.41	0.25	99.74	6

[a] The high content of FeO noted in the C horizon of profile 420 has also been retained here (frc depths of 5 to 12 cm. the FeO content is 3.8%, from 30 to 40 cm. 6.7%, from 120 to 130 cm. 8.9 in the basic rock, 12.6%).

preceding stage (see Table 2), the content of this fraction is decreased only by a factor of 3 to 3.5. Thus, the extent of disintegration of the material has almost doubled. A distinctive property of the soil texture at this stage is the differentiation of the illuvial horizon.

At this stage, significant changes are observed in the total composition of the soil (Table 6). The accumulation of silicate in the surface horizon, which was noted in the last phase of the previous development stage (profile 420), is considerably greater here. Data on the total content of the remaining components of the fine earths, complete mineralogical analysis by Ye. A. Yarilova and analysis of the ash from the pines growing on these soils enable us to establish the causes of this phenomenon. The accumulation of the greater part of the silicate is relati while its absolute accumulation evidently ta place in small amounts by biological accumu tion. According to Makeyev's data (2), in top parts of pines growing on sod-forest s which have developed on traps, the SiO_2 cumulates in quantities twice as large as in pi growing on the sod-podzolic soils of Europ USSR. But the relative accumulation of S takes place both because of the removal of al line earth cations (removal of CaO was observ in the preceding soil development stage) and a because of the intensive removal of iron, wh is the principal specific characteristic of the st now being considered. It is interesting to no that when the data on the total soil compositi as a whole are compared with those of the cla fraction, certain "discrepancies" are observe According to the total composition of wh soil, there is differentiation of the profile in th first 0.5 m. The clay fraction does not show th differentiation. We assume that this is caused b the considerable iron content in the compositio of primary minerals. These gradually add to th iron content of the clay fraction. In other word the reason for the iron loss in this stage is n the destruction of the aluminum-iron-silica complex, but the removal of free sesquioxid formed when the rock is weathered.

According to data from the thermal analysi the hydrated iron oxides have been observed on

TABLE 7

Physicochemical characteristics of sod-forest podzolized soils developed on residual traps

rofile No.	Depth, cm.	pH of water suspension	Humus as % of oven-dry soil (Tyurin's method)	Exchangeable cations (Gedroits method) me. per 100 gm. of oven-dry soil			$\frac{Ca}{Mg}$	As % of total Ca + Mg	Content of fraction <0.001 mm. as % of oven-dry soil	Adsorption capacity for Ca + Mg in me. per 100 gm. of clay	Exchangeable acidity (Daikuhara's method)	Hydrolytic acidity (Kappen's method)
				Ca	Mg	Total					in me. per 100 gm. of oven-dry soil	
7C	0–5	6.7	6.2	13.9	7.6	21.5	1.8	65	17.9	120	0.2	9.1
	5–12	6.5	1.5	7.6	8.7	16.3	0.9	47	16.5	99	0.2	2.4
	12–22	6.8	0.8	9.5	8.7	18.2	1.1	52	24.1	76	0.4	0.8
	30–40	6.6	0.7	14.0	9.5	23.5	1.5	60	14.6	161	0.3	0.5
	120–130	6.8	0.7	13.0	9.7	22.7	1.3	57	9.6	236	—	0.5

horizon C, while in the preceding soil develop- ent stage they were present throughout the rofile.

The decrease in the MgO content of the surface orizons in profile 7C evidently indicates the de- ruction of the montmorillonite minerals. This confirmed by the data from direct mineral- gical examination (2). Thus, at this stage of evelopment, the removal of iron is accompanied y the partial destruction of the secondary clay inerals. This destruction evidently takes place itially at separate individual points ("micro- egions") at which the particles are freed from e films of iron oxide and organic iron com- ounds.

All the information considered here shows that e principal specific characteristic of this soil enus is the large amount of iron. The iron and rganic iron films preserve the secondary min- rals from destruction and thus inhibit the forma- ion of podzols even after the calcium and mag- esium have been removed.

At this development stage the reaction in the pper soil horizons does not become more acid the pH of a water suspension is 6.5 to 6.8), ut a slightly acid reaction is distributed through- ut the entire profile (Table 7). In the upper art of the soil a noticeable hydrolytic acidity displayed. Regardless of the severe weathering f the mineral part of the soil, a reserve of pri- nary minerals has been saved. This is adequate o serve as a source for cations to neutralize he acid organic products. The conversion of inerals in weathering proceeds by stages. Dif- erent stages may begin at separate centers of oncentration of certain minerals at different imes. As a result of the collective action of the ations in forms capable of neutralizing acid solutions, there is sometimes an increase and sometimes a decrease (and the general tendency is to decrease) in the cation content in the soil as a whole. A pronounced decrease in the content of exchangeable Ca + Mg and in the adsorption capacity per 100 g. of the clay fraction develops, as compared to the previous stage. The relative calcium content in the composition of the exchangeable cations also decreases noticeably in this stage.

The humus content of the upper 0.5 m. of soil is about the same as that in the last phase of the preceding stage. Of substantial importance is the more rapid decrease with depth in the humus content. This is characteristic of podzolic soils. Also important is the noticeable penetration of humus to great depths along the profile, evidently resulting from an increase in the mobile fraction of the humic material. During the course of the further development of the podzolic process these soils are converted to sod-podzolic soils. Such soils have already been described, particularly by I. A. Shul'ga (8).

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Methods

MATERIALS IN THE FOREST'S BIOLOGICAL CYCLE OF NITROGEN AND PHOSPHORUS

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THE study of relationships between forest vegetation and soils has great theoretical and practical significance. It is known "that forest is a geographical phenomenon, of which the various forms and their life cannot be understood without connecting their formation with the external or geographical environment" (4, p. 89). The forest, which receives nitrogen, mineral elements, and moisture from the soil, also exerts an effect upon it. In the study of relationships between plants and soils, a special place belongs to the question of the amounts of essential nutrients taken up by plants and the biological cycle. At present, there are two opinions on this question. One of these was developed in some work of N. P. Remezov and his coworkers (1, 5, 6, 7), and the other by A. F. Tyulin (8, 9, 10).

N. P. Remezov's approach to the study of relationships between plants and soils consists essentially of the following: As in methods accepted for taxation work, a series of sample areas are established on one forest type with uniform soil conditions, but on plantations of different age classes. Model trees, characteristic for the given stand of timber, are chosen. At one time of year, August or early September, the model tree is cut, the limbs trimmed, the leaves (needles) picked, and the root system dug out. Later, the separate masses of leaves, small and large branches, trunk, large and small roots are determined by weighing. The weight of the whole tree is obtained by adding the weights of separate parts. From all parts, representative samples are prepared for chemical analysis. Further, the litter is collected during the entire growing season. For this, ten special boxes with an area of one square meter are placed on each sample area. The litter is collected regularly and is used to determine the nutrients returned by the plants to the soil (2, 7).

In the opinion of N. P. Remezov, three quantities characterize the biological cycle of nutrients in the forest: the amounts of nutrients 1) entering the cycle, that is, withdrawn from soil by trees; 2) held in the stand of timber; and 3) returned to the soil in litter and dying trees. The amount of nutrients taken into the biological cycle is determined in the following way: 1) the contents of mineral elements in separate parts of the tree give an idea of the quantity held in the stand of timber; 2) the contents of these elements in the litter and dead wood tell how much is returned to the soil. The sum of these two quantities shows the total amount of nutrients withdrawn from the soil by trees, that is, entering the biological cycle.

Using this method, N. P. Remezov found, depending on the forest type, that 44 to 156 kg. of nitrogen and 14 to 46 kg. of phosphorus per hectare entered the biological cycle.

A. F. Tyulin advanced some entirely reasonable objections to Remezov's approach. He noted that "the biological cycle includes two cycles—annual and perennial." Remezov's method allows the study of the perennial cycle, but does not fully reflect the annual cycle (8).

A. F. Tyulin quite correctly pointed out that Remezov did not completely consider the paths of returning mineral elements, but considered only litter and dying trees. He did not consider other sources of returning mineral elements to soil, such as root excretions and dying parts of fine rootlets, especially the absorbing ends of roots, encircled by the rhizosphere of microorganisms. A. F. Tyulin quotes experiments of

A. I. Akhromeyko, using tagged atoms, which showed that oak and ash seedlings in only one day excreted from the roots 6 to 12% of the phosphorus absorbed by them. The very fact of root excretion of mineral matter, and the first quantitative measurement of this, confirms the truth of the preceding remarks. Furthermore, A. F. Tyulin considered that a basic weakness in Remezov's method was that, instead of measuring the amount of nutrients taken directly into the biological cycle by living plants interacting with the soil, it determined the total quantity in sawed-off trees, in roots, and in collected litter. That is, it measured the static accumulation of nutrients in killed plants after an arbitrary period of time.

Regarding the weaknesses of Remezov's method, Tyulin pointed out that "for the quantitative determination of mineral elements actually taken into the biological cycle, it is necessary to study the seasonal variation in nutrients in the soil and in roots during the growing season" (8).

In order to confirm his ideas, Tyulin made observations on the dynamics of carbon, nitrogen, and phosphorus in the Tellermanov experimental forest, Forestry Institute, Academy of Sciences, USSR (8, 9, 10).

From Tyulin's data it is clearly the rule that during the first half of the growing season a decrease in carbon, nitrogen, and phosphorus is observed in the soil, but in the second half the opposite occurs. The lowest amounts of these elements occurred in the months of June and July.

TABLE 1

Dynamics of humus, nitrogen, and phosphorus in percent of the soil weight

Horizon	Date of sampling	Pine				Birch			
		Humus	N	C:N	P_2O_5	Humus	N	C:N	P_2O_5
A_1	May 21	1.94	0.114	9.93	0.033	4.14	0.394	7.85	0.083
"	July 1	1.85	0.073	14.97	0.020	3.41	0.255	7.74	0.054
"	July 23	1.47	0.028	30.38	0.023	4.24	0.345	7.11	0.068
"	Sept. 4	2.15	0.115	10.81	0.044	4.14	0.305	7.85	0.071
A_2	May 21	0.37	0.017	12.58	0.024	1.19	0.055	12.52	0.062
"	July 1	0.31	0.022	8.14	0.022	0.99	0.046	12.46	0.050
"	July 23	0.42	0.017	14.88	0.025	0.99	0.051	11.23	0.060
"	Sept. 4	0.82	0.028	17.57	0.025	1.24	0.077	9.31	0.082
B	May 21	—	—	—	—	0.36	0.021	9.90	0.039
"	July 1	0.39	0.024	9.38	0.057	0.19	0.023	4.78	0.030
"	July 23	0.39	0.028	5.35	0.010	0.19	0.027	4.78	0.038
"	Sept. 4	0.46	0.044	0.04	0.010	0.39	0.023	8.30	0.043

From calculations of the decrease in nitroge in the soil, A. F. Tyulin showed that the amoun of nutrients taken into the biological cycl quoted by Remezov, should be increased abo ten times. Thus, on the basis of Tyulin's exper mental data, the incorrectness of Remezov's a proach to the study of amounts of mineral ma ter taken by woody plants into the biologic cycle has been conclusively demonstrated.

In agreement with Tyulin's fully justifi remarks and guided by his proposed method, w carried out analogous work during the summe of 1955 and 1956. In 1955, observations on th dynamics of total humus, nitrogen, and pho phorus were carried out on the Raif forest re serve. For this purpose, three pines and thr birch of the same age (25 to 30 years) an harvest condition were chosen. The soil unde pine was moderately podzolized friable san and under birch weakly podzolized coarse cla loam. Samples were taken from the A_1, A_2 and B horizons. The samples from the sam horizon under each tree were combined an carefully mixed. Samples were taken on May 21 June 1, July 23, and September 4. Humus wa determined by the method of Tyurin, nitroge by that of Kjeldahl, and phosphorus, afte fusion with alkali, colorimetrically by th method of Denige as modified by Malyugin an Khrenov. The analyses were carried out by E D. Lyapushkin. The results are presented i Table 1.

In spite of the fact that our observations wer carried out with different species and ecologica conditions, the results agreed with those of Tyulin. The contents of humus, nitrogen, and phosphorus decreased from spring to the end of th first half of the summer, and later began agai to increase. This rule was followed not only i the upper horizons, but also in those underneath The changes in content of humus, nitrogen, an phosphorus were clearer under birch.

Observations in 1956 were carried out in forest near the Observatory station, on a coars clay loam moderate sod podzol. For observatio a portion of deciduous forest 45 to 55 years ol was chosen, with a predominance of linden undergrowth. In addition to linden, there wer Norway maple, smooth elm, warty birch, an aspen; in the underbrush, common hazelnut; i the ground cover, goutweed, hairy woodrush European asarabacca, common strawberry ground ivy, and others. Soil and fine roo mples were taken on this plot under three ndens of normal growth and with about the me degree of lighting and crowding. Leaves om the lower branches of these trees were also ken for analysis. Soil samples were taken from he 3 to 13 cm. layer, every sample being composited from four different points near the circumference of the crown projection. Samples f roots and leaves were taken simultaneously vice monthly from the beginning of May until he end of August. The roots, washed free of dhering soil particles, and leaves were fixed n the second day after gathering. They were eated with a stream of steam which stopped nzyme action. Then the samples were dried and round in a hand mill. In the soil samples, total ontents of humus, nitrogen, and phosphorus ere determined by the same methods as in 1955. n the root and leaf samples, total nitrogen content was determined by the Kjeldahl method, nd total phosphoric acid was determined colorietrically after dry ashing.

As Table 2 shows, at the end of June and eginning of July (at the period of maximum rowth of woody and herbaceous plants), a ignificant decrease in all three components is bserved in the 3 to 13 cm. soil layer, where the reatest quantities of fine roots are concentrated. his period coincides with the time of complete owering and fruit formation of linden. The derease was noted in all three replicates. In the ntire month of June it rained very little, the eather stayed dry and hot, and leaching of hese elements into lower soil horizons could ot have occurred. Rather, we might assume the pposite; that during this time there was a flow f moisture which could have transported solble mineral elements from the lower soil horions. But, as may be seen in Table 2, no increase n the content of these elements was observed up to the end of July. The second half of the summer was characterized by increased contents of humus, nitrogen, and phosphorus.

Thus, we again obtained results in agreement with those of Tyulin. In both cases there is observed a regular decrease in humus, nitrogen, and phosphorus in the soil during the first half of the summer and an increase in their contents in the second half. Most of all, the absolute amounts of the decreases and times of minimum contents of the elements determined in the soil agree closely within themselves.

Now we turn to data on the changes in contents of nitrogen and phosphorus in roots and leaves during the growing season. They are presented in Table 3 (average of three replicates).

As may be seen from the data, the nitrogen content in the roots increases somewhat from May 5 to 20, then decreases, gradually at first, but more markedly by July 27. On August 7 and 25, increases are again observed in the nitrogen contents in the roots. Phosphorus behaves similarly except that the decrease in its content begins May 5, and continues steadily until July 27. After that the content of phosphorus again increases markedly. Comparing the changes in nitrogen and phosphorus contents in soil and in roots during the growing season, it is easy to observe similarities, and some differences, in their behavior. The similarity is that in soil as in roots the nitrogen and phosphorus contents decreased beginning May 5; but in soil the decreases continued until June 20, or July 5, in roots until July 27, inclusively. Correspondingly, the increases in soil nitrogen and phosphorus contents began on July 5 or 27, but in roots on August 7.

With regard to changes in the nitrogen content in the leaves, the following must be noted.

TABLE 2

Contents of humus, nitrogen, and phosphorus in the 3 to 13 cm. layer of soil

Date of sampling	First tree				Second tree				Third tree			
	Humus	N	C:N	P_2O_5	Humus	N	C:N	P_2O_5	Humus	N	C:N	P_2O_5
May 5	7.44	0.335	12.9	0.092	6.37	0.254	14.5	0.082	—	—	—	—
May 20	6.07	0.242	14.5	0.081	5.58	0.193	16.7	0.071	5.52	0.220	14.5	0.073
une 20	5.09	0.208	14.2	0.072	5.32	0.215	14.3	0.068	5.00	0.218	13.3	0.066
uly 5	6.37	0.253	14.5	0.076	4.71	0.202	13.5	—	3.92	0.172	13.2	0.068
uly 27	6.20	0.255	14.0	0.079	5.09	0.217	13.6	0.062	4.61	0.175	15.2	0.071
ug. 7	7.60	0.303	14.5	0.079	5.40	0.251	12.8	0.065	4.66	0.183	14.7	0.074
ug. 25	8.13	0.311	15.1	0.087	6.37	0.278	13.3	0.070	5.92	0.215	15.9	0.079

TABLE 3

Dynamics of nitrogen and phosphorus contents in roots and leaves, percent of air-dry weight

Date of sampling	Roots		Leaves	
	N	P_2O_5	N	P_2O_5
May 5	0.952	0.498	—	—
May 20	1.005	0.415	4.733	2.113
June 20	0.903	0.381	2.708	0.871
July 5	0.915	0.342	2.392	0.784
July 27	0.810	0.331	2.638	0.806
August 7	0.854	0.394	2.537	0.931
August 25	0.850	0.377	2.191	1.090

On May 20, when only one fourth of the leaves were developed, their content approached 5%, but on June 20, it was sharply reduced. Later, after some decrease on July 5, the nitrogen content stayed about the same until August 7, and again decreased markedly at the end of August. The phosphorus content of leaves behaved similarly to the nitrogen content until July 5, but gradually increased from July 27, to the end of August.

On the basis of the data obtained, we concluded the following:

1. The roots of linden extract nitrogen and phosphorus from the soil until June 20 or July 5, after which the delivery of these elements to the above ground parts proceeds only by their translocation from the root system.

2. Apparently, the increase of nitrogen and phosphorus content in the soil proceeds both because of decomposition of parts of root hairs, and because of root excretions.

3. At the end of the growing season, when tree growth is ended and the fruits have formed, increases in nitrogen and phosphorus contents take place in the roots as well as in the soil. Besides the reasons indicated in paragraph 2, a stream of these elements from the top parts of the tree also contributes to this.

The last conclusion is supported by the nitrogen content of the linden leaves. It gradually decreases at the end of the growing season, but the phosphorus content does not.

The data for root and leaf analyses obtained by Tyulin differ somewhat from ours. Although the behavior of nitrogen and phosphoric acid he observed in the leaves agreed with our data, the behavior of these elements in the roots showed some discrepancies. Thus, Tyulin's data show that the nitrogen content of the roots clearly decreased at the beginning of the growi season; in July the content increased a changed very little after that. Changes in t phosphorus content were opposite to that nitrogen. At the beginning of growth pho phorus content increased (Tyulin postulated t uptake of large amounts of sesquioxides at th season, which were abundant in the soil whe the experiments were carried out), but lat decreased sharply, and in August changed ve little (9, 10—Figs. 2 and 3, p. 275).

Apparently, the differences in behavior nitrogen and phosphorus observed by Tyul and ourselves are explained, first, by the di ferent ecological conditions of the experime and, second, by different physiological characte istics of the species investigated. Biochemic processes occurring in the life of plants, esp cially in leaves, are very complex. Therefor without special physiological investigations, is difficult to explain certainly the behavior c mineral elements.

Turning to the dynamics of mineral element in soils, it must be stressed that we obtaine the same results using Tyulin's method. Anal yses of deeper soil layers, made by Tyulin an by ourselves in Raif, showed similar conclusion to those in the upper layers.

The existing scanty data in the literature o seasonal exchange of mineral matter by differen plant species support the correctness of th method of Tyulin's proposed investigation. W may point out, for example, experiments of V D. Gotsulyak (3) with seedlings and planting of oak and ash. This author showed that two-year–old plantings of oak and ash had a larg requirement for nitrogen in the first half of th growing season—in May, June, and July. During this period they used about 70% of the nitrogen absorbed during the entire growing season In the same experiments, an outward flow o nutrients into the soil was observed from seedlings and plantings for about a month befor the end of the growing season. The results o our work and Tyulin's investigations testify t the same thing.

On the basis of our data, we calculated th amounts of nitrogen and phosphorus taken int the biological cycle by forest vegetation. Fron Table 2 it is seen that the seasonal decrease i nitrogen in the 3 to 13 cm. soil layer on Jun 20 amounted to 0.335 − 0.208 = 0.127 g., an in phosphorus, 0.092 − 0.072 = 0.02 g. Assumg that the weight of this soil layer equals 650 ns per hectare (proceeding from estimates of yulin, according to which the weight of the il layer to 30 cm. equals 2000 tons per hec- re), the seasonal decrease in nitrogen in this yer will only amount to 825 kg. per hectare, nd phosphorus 130 kg. per hectare. For the il layer to 20 cm. these figures must be oubled. It is recognized that these estimates do ot have great accuracy. Nevertheless, it must e noted that they are very close to those ob- ined by Tyulin, and sharply different from ose obtained by Remezov for linden.

Conclusions

1. The dynamics of humus, nitrogen, and hosphorus contents in the upper and lower soil orizons show quite definite regularity, ex- ressed as a gradual decrease in the content of hese elements in the first half of the growing eason, and an increase in the last half.

2. The minimum content of these elements in he soil occurs at the end of June or beginning f July.

3. The dynamics of nitrogen and phosphorus ontents in roots and leaves show about the ame regularity as their dynamics in soils, hough the seasonal decrease in roots is some- hat more drawn out than in leaves. At the nd of the growing season the nitrogen and hosphorus contents in roots increase. In leaves hese elements behave in an opposite manner, amely, the nitrogen content at the end of rowing season decreases, but phosphorus, on he contrary, increases.

4. A rough calculation of the decrease in itrogen and phosphorus in soils in the first half f the summer shows that the amounts of these lements taken into the biological cycle during he growing period are very close to the amounts btained by Tyulin, but differ sharply from hose found by Remezov for linden stands.

5. The method proposed by Tyulin for study- ng mineral exchange between plants and soils ppears more correct than the method used by Remezov and his co-workers, inasmuch as the atter did not consider those changes which oc- urred in the soil under the influence of living plants.

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THE BROWN FOREST SOILS OF THE KODRY

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THE great soil group of the brown forest soils ("brown earths"), which was named by E. Ramann in 1908, has been considered as characteristic of Central Europe. It is generally recognized that brown forest soils are a zonal type; their areal distribution corresponds to that of broad-leaved forests in regions with a moderately moist and warm climate. These soils are widespread in Germany, Poland, Bulgaria, Hungary, and Rumania. In the USSR they are located in the Crimea, the Caucasus, the mountainous regions of Central Asia, in the Far East and in the Transcarpathia.

In the Kodry of Moldavia brown forest soils were first separated by N. Florov in 1938 under the designation "Soluri brun roscate de padure" (18). On pre-1953 soil maps of the Soviet Union only gray forest soils were distinguished in the Kodry. The question was raised in 1948 as to whether brown forest soils exist here (9, 8, 4, 5). On the 1:1,000,000 Soil Map of the USSR, published in 1953 by the V. V. Dokuchayev Soil Institute, considerable areas of the Kodry are shown as brown forest soils. However, the question of the formation of this group in the Kodry remains debatable.

The Kodry occupies the central, most elevated part of Moldavia and is delimited as an independent terrain unit characterized by unique relief, vegetation and soil cover. The Kodry has a type of relief with low mountains of erosional origin with maximum elevations of about 430 m. above sea level. The area's climatic conditions relate it to districts having a climate transitional between the moderately moist and warm type and the continental type. Annual precipitation averages 500 to 600 mm. per year. The mean annual temperature is +9.5° C. The parent material in the more elevated part of the Kodry consists of residual and alluvial deposits from the Sarmatian, while at lower elevations it is loessial clay loams.

The Kodry district can be divided into two parts according to the nature of the vegetation: the "forest primeval"—the more elevated part of the northwest and central Kodry which has retained its forest cover from the end of the Tertiary; the forest-steppe, which embraces t lower-lying peripheral part of the Kodry. T complex soil-forming conditions of the Kod have made possible the formation of both fore and chernozem soils. The chernozems are ass ciated chiefly with the periphery at elevatio up to 260 m. above sea level.

The following pattern is evident in the ge graphical distribution of forest soils: in t high (northwest and central) Kodry, brow forest soils are the most widespread; gray fore soils achieve increasingly wide distribution a the distance from the center increases and th elevation decreases. In this distribution eve the most nearly "typical" soils are different fro those soils in the northern districts of Moldavi and on the forest-steppes of the European plai which resemble the brown forest soils.

One of the most important genetic charac teristics of the brown forest soils is the hig clay content of the soil profile, which is co sidered to be a result of deep metamorphis of the primary minerals or, in other words, c "clay weathering." Rozanov, describing th genesis of the brown forest soils of Central Asi (14), states that, owing to certain biohydr thermal conditions occurring naturally in thes soil regions, the highest clay content appears i the middle profile, where there are thermal an hydrological conditions most constant and fa vorable for clay weathering. When such cla formation takes place there is also accumulatio in the soil profile, simultaneously with that c the clay and colloid particles, of sesquioxides c aluminum and iron, as well as oxides of ma ganese, phosphorus, magnesium, calcium an others. This differs from the gray forest soil in which clay weathering also takes place bu is rather a predominantly illuvial transfer c colloids and clay from the upper profile to th middle. In brown forest soils the clay is forme chiefly *in situ* with little or no illuviation.

A number of investigators (12, 2, 11 an others) have shown that the brown forest soil of the Crimea, the Caucasus, the Far Eas France, Switzerland and other regions are cha acteristically podzolized as manifested in th higher ratio of SiO_2 to R_2O_3 in the soil than in he parent material. One of the differential characteristics of brown forest soils is their high degree of saturation with adsorbed cations, although unsaturated brown forest soils are also encountered fairly often.

Examination of the brown forest soils of the Kodry showed that they had all the basic characteristics of this soil group: a fairly pronounced clay content accumulation of sesquioxides (especially of aluminum) and of phosphorus, manganese, magnesium and other elements along the entire profile; and a high degree of saturation with adsorbed cations. Depending on the extent to which they are podzolized, the brown forest soils of the Kodry may be divided into non-podzolized saturated brown forest soils and podzolized brown forest soils, but it should be noted that the latter are only slightly podzolized.

Saturated Brown Forest Soils

These soils are located on narrow crests dividing watersheds and on steep slopes mostly with western exposures and elevations to 260 o 400 m. above sea level. A general idea of the morphology of these soils can be obtained from the following soil description:

The area which is the source of profile 102K is located in the Bumbot forest on a slope with a western exposure and an elevation of 320 m. under forest cover consisting of oak, hornbeam, maple, ash and cherry. The grass cover is made up of sedges, European wild ginger and ground ivy.

A_0 0–1 cm. Half decomposed forest litter.

A_1 1–9 cm. Cinnamon-brown, gray with a brown tinge, granular fine nutty structure. Transition to following horizon gradual.

AB 9–17 cm. Grayish cinnamon-brown, brownish coarse clay loam with granular-fine blocky structure. Transition gradual.

B_1 17–32 cm. Dark-brown, grayish coarse clay loam with rounded granular fine nutty structure, somewhat compacted. Transition gradual.

B_2 32–70 cm. Brown with a gray tinge in the upper part and ocher-colored in the lower; clay loam; blocky structure; on the faces of individual peds there is a slight gray-brown film; compacted. Transition gradual.

BC 70–88 cm. Ocherous-brown with red-brown and ocher-colored spots, friable, sandy. Abrupt, uneven line of transition to C horizon.

C below 88 cm. Marl containing 15 to 30% of clay, spotty olive-white color with layers of fine sand. There is effervescence with 10% HCl below 88 cm.

Table 1 shows that saturated brown forest soils are characteristically clay-containing profile without any removal of colloidal clay from the upper part.

The data from a total chemical analysis, which are given in Table 2, are typical for non-podzolized brown forest soils. The SiO_2 content is almost uniform along the profile without any pronounced accumulation in the top horizon. There are notable accumulations of manganese and phosphorus and somewhat smaller ones of iron, aluminum and magnesium. The accumulation of iron, manganese, magnesium and calcium and of other oxides shows how intensive the clay weathering of these soils has been. Such weathering has resulted in a considerable degree of repacement of any oxides which have been removed.

Brown forest soils under forest cover contain 4 to 8% of humus in the top 30 cm. layer. In soils under crops a noticeable decrease in the humus is observed (Table 3). In soils which have emerged from forest cover, the nitrogen content has also decreased, especially in coarse-textured soils. The saturated brown forest soils of the Kodry characteristically have a narrower C:N ratio than do other soils. While in the saturated brown forest soils, the ratio is from 8.2 to 12.3 to 1, in the gray forest soils of the Kodry it varies from 10.9 to 13.8 to 1, and in the chernozems from 10.5 to 12.2 to 1. In the brown forest soils of the northwestern Caucasus the ratio is 14 to 1 (7), while in the brown forest soils of northern Ossetia it is about 10 to 1 (13). The brown forest soils of the Kodry, like those of other regions, are highly saturated with exchangeable cations (Table 3). The total contents of adsorbed calcium and magnesium reach 29 to 43 me. per 100 gm. of soil in the top 30 cm. layer. Here, most of the adsorbing complex consists of calcium, which occupies 78 to 93% of the adsorption capacity. Only 1 to 5% of the capacity is taken up by adsorbed hydrogen ions. Another characteristic of saturated brown forest soils is the gradual decrease in the content of adsorbed cations with depth, but between the 15 and 24 cm. levels only slight decreases are sometimes seen. A result of the high degree of saturation of brown forest soils with exchangeable cations is their very low acidity (the pH of a KCl suspension is 6.5 to 6.9; it only occasionally goes as low as 5.7).

TABLE 1

Texture of brown forest soils (Analyses by N. V. Dmitriyeva, R. I. Luneva and G. P. Strizhova)

Profile No.	Location	Depth, cm.	Hygroscopic moisture, %	Content in % of particle diameters in mm.:							Loss or gain in fra tion as % of its co tent in parent material	
				1–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.0055 0.001	< 0.001	< 0.01	<0.001	<0.01
						Saturated brown forest soils						
102 K	Bumbota (forest)	1–9	3.2	5.2	16.8	48.7	6.1	3.9	19.3	29.3	+12.2	+4.
		21–31	2.9	14.7	46.9	10.3	6.3	2.1	18.8	27.2	+9.3	−2.
		36–46	2.4	17.8	39.4	9.5	10.6	3.3	18.5	32.4	+7.6	+15.
		53–63	2.6	4.5	54.4	10.8	4.1	5.3	20.9	30.3	+21.5	+8.
		121–131	2.5	0.7	35.7	24.6	4.7	6.1	17.2	28.0	0	
1132	Sadovo (plowland)	5–15	1.3	0.6	67.9	13.1	1.6	3.1	13.6	18.4	+26.0	+33.
		30–40	1.7	0.5	71.8	7.8	1.3	2.9	15.7	19.9	+45.4	+44.
		48–58	1.8	0.5	72.8	6.7	1.6	2.3	16.0	19.9	+63.0	+44.
		70–80	1.6	0.4	76.1	5.8	1.3	2.1	14.2	17.7	+31.5	+28.
		140–150	1.3	0.3	80.4	5.6	0.4	2.6	10.2	13.8	0	
						Podzolized brown forest soils						
50 D	Kapriyany (forest)	2–10	3.7	2.2	27.8	24.0	13.4	14.8	17.8	46.0	−27.3	−19.
		20–30	4.8	5.6	19.4	27.9	19.0	9.0	19.1	47.1	−22.0	−17.1
		50–60	5.9	3.9	11.6	27.0	18.4	12.7	26.4	57.5	+7.7	+1.2
		65–75	6.5	2.1	11.0	29.6	12.2	12.5	32.6	57.3	+33.1	+0.9
		110–120	5.4	2.3	15.7	19.4	14.9	17.5	30.2	62.6	+23.1	+10.2
		140–150	4.7	4.5	21.1	17.6	14.3	18.0	24.5	56.8	0	0
3 D	Lozovo (forest)	3–8	6.0	7.7	27.7	16.8	11.0	10.4	26.3	47.7	−9.6	+3.7
		8–12	6.6	5.4	28.2	21.4	5.8	10.7	28.6	45.1	−1.7	−2.0
		15–24	4.9	3.8	40.6	10.3	9.0	6.4	30.0	45.4	+3.1	−1.3
		25–35	5.4	2.1	40.6	9.8	8.9	7.2	30.5	46.4	+4.8	+0.9
		45–55	4.7	2.5	42.4	8.4	7.3	6.8	32.5	46.6	+11.7	+1.3
		55–65	4.6	2.0	37.8	10.0	6.7	7.8	35.7	50.2	+22.7	+9.1
		90–100	5.0	1.8	32.1	18.6	6.0	7.7	32.5	46.2	+11.7	+0.4
		210–220	3.0	0.3	39.9	18.9	8.9	8.0	29.1	46.0	0	0

Podzolized Brown Forest Soils

These soils are very widespread in the Kodry and are encountered both on watershed plateaus and on slopes of varying steepness and exposure at elevations of 260 to 400 m. above sea level. The morphological characteristics of these soils are: a) a brown colored profile with a gray tinge in the upper part and dark brown in the lower; b) gradual horizon transitions; c) a well-expressed B horizon having great thickness, firm consistence, a brown or dark brown color and inclusions with sesquioxide films (often with SiO_2 grains); d) an A_2 horizon which is morphologically either vague or lacking. The soil texture varies from clay to sandy loam. The typical morphological characteristics of these soils are seen from the following descriptions:

Profile 3E. From a watershed plateau at a altitude of 300 to 360 m., south of the villag of Lozovo, in a wood made up of hornbeam linden and oak. Grass cover consisted of sedges

A_0 0–3 cm. Half decomposed litter.

A_1 3–12 cm. Gray-brown clay loam extensivel penetrated by roots especially in the upper cm.; rounded granular-fine nutty structure Transition gradual.

AB 12–25 cm. Brown grayish clay loam with faint rounded nutty-blocky structure, extensivel penetrated by worm holes. Transition gradual.

B_1 25–38 cm. Brown with gray spots, clay loam friable, with rounded fine nutty structure; many coproliths. Transition gradual.

B_2 38–66 cm. Brown with reddish tinge; fine clay loam; compact; structure fine nutty-blocky; o the faces of the peds, reddish films and manganese dots.

TABLE 2

Total chemical analysis of brown forest soils (Analyses by N. N. Safronikov)

Profile No.	Location	Depth, cm.	Hygroscopic moisture, %	Loss on ignition, %	As % of ignited carbonate-free soil							Molecular ratio SiO_2
					SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	P_2O_5	R_2O_3
Saturated brown forest soils												
67 D	Kapriyany (forest)	5–15	5.8	11.56	71.02	13.32	10.05	—	1.69	2.69	—	3.0
		30–40	6.2	6.70	67.61	16.11	9.70	—	2.12	2.62	—	3.6
		55–65	6.2	7.04	66.74	15.97	10.01	—	2.20	3.06	—	2.6
		105–115	6.2	10.08	65.80	19.50	7.56	—	2.30	3.26	—	2.4
		150–160	5.2	19.20	65.41	16.30	8.56	—	0.90	3.13	—	2.6
1132	Sadovo (plowland)	5–15	1.3	3.30	86.28	6.12	2.45	0.60	1.01	0.31	0.65	10.1
		30–40	1.7	3.40	87.36	5.43	2.83	0.38	0.79	0.61	—	10.7
		70–80	1.6	2.90	85.68	7.67	2.07	0.45	0.82	0.50	0.62	8.8
		140–150	1.3	2.20	86.68	5.30	2.79	0.31	1.20	0.45	0.47	10.7
1133	Sadovo (plowland)	2–12	2.6	6.50	85.12	7.52	2.48	0.46	1.17	0.47	0.53	8.5
		28–38	3.1	5.70	80.36	11.02	2.87	0.48	1.02	0.52	0.59	5.7
		45–55	3.5	5.30	80.55	9.21	4.01	—	1.21	0.71	0.59	6.0
		68–78	3.5	4.50	82.08	8.68	2.63	0.25	0.87	0.37	—	7.2
		90–100	2.7	3.90	82.57	9.48	2.36	0.25	0.91	0.37	0.22	7.0
Podzolized brown forest soils												
50 D	Kapriyany (forest)	2–10	3.7	9.32	80.13	10.26	3.77	—	1.75	1.08	—	5.7
		20–30	4.8	3.81	80.31	9.12	5.56	—	0.84	1.08	—	5.5
		65–75	5.9	3.33	77.41	11.96	5.32	—	1.31	1.29	—	4.5
		140–150	4.7	9.04	80.48	7.88	6.04	—	2.67	1.36	—	5.8
In colloidal clay fraction (as % of ignited material)												
		2–10	9.33	13.13	57.40	22.23	10.58	—	1.90	2.66	0.30	1.7
		20–30	8.56	10.24	59.70	23.64	9.56	—	0.99	2.43	0.21	1.8
		65–75	11.31	9.65	58.25	24.41	10.39	—	0.50	2.61	0.17	1.7
		140–150	11.75	9.38	60.50	23.00	10.32	—	0.35	3.19	0.16	1.8

B$_3$ 66–84 cm. Brown with a reddish tinge; clay; firm; prism-like coarse blocky structure; falls apart into small nutlike fragments; faces of the peds have a brown film of sesquioxides and manganese dots.

3C 84–98 cm. Brown-ocherous, heterogeneous, clay loam with spots of sandy loam; structureless; spots of sesquioxides and manganese.

BC 84–98 cm. Brown-ocherous whitish marly clay loam with spots of sand.

The results of the particle size and chemical nalyses (Tables 1, 2 and 3) are evidence of he negligible podzolization of these soils. They ave a typical characteristic of brown forest oils: occurrence of clay along the profile. The emoval of colloidal clay particles takes place sually only from the top 15 to 30 cm. depth nd never becomes large.

Data from the total chemical analysis of podzolized brown forest soils show that in the podzolized part of the profile there is deeper weathering, the products of which descend in the form of fine clay and colloidal suspensions to form the illuvial horizon. However, this process is only weakly manifested and there is considerable compensation for it over the entire profile in the accumulation of oxides resulting from weathering within the soil. In this connection, a typical trait of podzolized brown forest soils is the simultaneous combination of eluviation, especially of the oxides of alkaline earth metals, with the accumulation of sesquioxides along the entire profile. Table 2 shows the occurrence in the soil of a negligible accumulation of SiO_2 in the upper horizons and of an increase in the Al_2O_3 and Fe_2O_3 content at a

TABLE 3

Content of humus and adsorbed cations and the acidity of brown forest soils
(Analyses by L. T. Bryukov, R. I. Luneva and K. I. Kurilko)

Profile No.	Location	Depth, cm.	Humus, %	CO_2, %	Adsorbed cations in me. (Gedroits method)				Hydrolytic acidity, me.	Degree of saturation	pH of KCl suspension	Exchang able acidit H + A (Sokolov metho
					Ca	Mg	H	Ca + Mg				
					Saturated brown forest soils							
67 D	Kapriyany (forest)	2–10	8.7	—	41.1	2.7	—	43.8	—	—	6.6	—
		15–25	6.7	—	34.7	2.5	—	37.2	—	—	6.5	—
		30–40	1.7	—	31.7	4.7	—	36.4	—	—	6.4	—
		80–90	0.9	1.9	—	—	—	—	—	—	6.2	—
		150–160	—	6.2	—	—	—	—	—	—	—	—
102 K	Bumbota (forest)	1–9	4.4	—	31.5	3.3	—	34.8	1.8	95.0	6.9	0.05
		10–19	3.7	—	31.8	2.5	—	34.2	2.0	94.4	6.8	0.09
		21–31	1.7	—	27.3	1.9	—	29.2	1.1	96.3	6.8	0.06
		36–46	1.0	—	28.9	2.3	—	31.2	0.7	97.7	6.7	0.04
		53–63	0.5	—	26.9	1.4	—	28.3	0.8	97.2	6.2	0.03
		121–131	—	15.2	—	—	—	—	—	—	7.2	—
1132	Sadovo (plowland)	5–15	1.5	—	10.5	2.0	—	12.5	1.2	91.3	9.8	0.18
		30–30	0.8	—	10.9	2.7	—	13.6	2.5	84.8	6.7	0.24
		70–80	0.6	—	11.2	2.6	—	13.8	2.8	—	6.9	0.14
		140–150	0.4	—	—	—	—	—	—	—	7.0	—
1133	Sadovo (plowland)	2–12	2.3	—	18.7	2.5	—	21.2	—	—	6.5	—
		15–23	1.5	—	20.3	2.9	—	23.2	—	—	6.2	—
		28–38	0.8	—	21.2	3.1	—	24.3	—	—	6.0	—
		68–78	0.3	—	—	—	—	—	—	—	5.7	—
					Podzolized brown forest soils							
50 D	Kapriyany (forest)	2–10	5.8	—	35.8	5.0	3.8	40.8	—	91.5	6.2	—
		20–30	1.0	—	21.8	5.5	4.6	27.3	—	85.6	6.1	—
		65–75	0.5	—	16.5	4.5	0.7	18.0	—	97.0	4.3	—
		120–130	0.3	—	8.8	1.6	—	10.3	—	—	6.2	—
		140–150	0.3	2.4	4.4	1.8	—	6.2	—	—	6.4	—
42 K	Guzun (field)	5–15	1.5	—	29.2	1.9	—	31.1	2.2	93.7	7.3	0.060
		30–40	0.8	—	35.8	2.7	—	38.5	0.8	97.8	6.8	0.025
		50–60	0.6	—	37.6	2.9	—	40.5	1.3	96.9	6.7	0.035
		70–80	0.5	—	38.2	3.2	—	41.4	1.1	97.3	6.5	0.075
5 D	Redeny (forest)	0–4	6.4	—	—	—	—	—	—	—	—	
		6–10	3.4	—	9.0	1.4	0.3	10.4	—	—	4.5	
		20–30	1.6	—	8.8	1.5	0.3	10.3	—	—	5.5	
		45–55	1.6	—	10.0	1.6	0.3	11.6	—	—	5.2	
		55–65	0.7	—	12.1	1.8	0.3	13.9	—	—	5.4	
		70–80	0.7	—	13.7	2.1	0.3	15.8	—	—	5.0	
		130–140	0.5	—	15.2	2.7	0.8	17.9	—	—	4.4	

depth of 40 to 80 cm., with a pronounced accumulation of Al_2O_3 along the entire profile.

Of special importance in soil genesis knowledge is the examination of the mineralogical and chemical composition of the colloidal clay particles. There are some papers giving characterizations of the mineralogical composition of the brown forest soils of the Caucasus (6, 13) and of the Crimea (1) in which it is noted that as a result of soil formation, there is vigorous weathering of the mineral part of the soil, especially in podzolized brown forest soils. During this process there is accumulation of intermediate products along the entire soil profile, with formation of a large amount of secondary clay minerals of the montmorillonite group.

There are, in general, no data on the mineralogical composition of Moldavian soils. There are only isolated reports on the mineral composition of the colloidal clay fraction of the brown forest soils of the Kodry (5). The following conclusion may be drawn from this: the largest group of components of the podzolized brown forest soils is composed of the secondary clay minerals (montmorillonite, beidellite, halloysite) and the final products of weathering—amorphous material. Thus, the mineralogical composition of the colloidal clay fraction of the podzolized brown forest soils of the Kodry is also evidence of the intensive clay formation in the profile. In this they resemble the brown forest soils of other regions.

The total content of oxides in the colloidal clay fraction by horizons is extremely specific for brown forest soils, so that it serves as one of the principal differential characteristics. Thus, the amount of silica in the colloidal clay fraction by horizons changes very little, increasing negligibly with depth. The aluminum and iron oxide content in the colloidal clay fraction also changes little by horizons, showing only a tendency to increase somewhat over that of the parent material (Table 2).

The study of the organic matter (humus) is of great importance in the understanding of the genesis and properties of soils. Research by I. V. Tyurin (16), M. M. Kononova (9) and others, has shown that differences in the composition by component groups of the humus between soil groups and sub-groups are determined primarily by the relative content of the two principle groups of humic substances—humic acids and fulvic acids. Speaking of the specific characteristics of the fractional composition of the humus of North Caucasus brown forest soils, Tyurin notes that a considerable part of the humic acids in the humus of these soils consists of fraction 1, that is, of brown (ulminic) acids. Fraction 2, the humic (black) acids proper, combined with calcium, is practically absent. The total content of humic acids in these soils is noticeably lower than that of fulvic acids. Ye. V. Rubilin, who investigated the fractional humus composition of the podzolized brown forest soils, central Caucasus northern slope, noted predominance by the fulvic acid group over the humic acid group (14). The humic portion of these soils consists mostly of humic acid fraction 1, that is, the fraction soluble in dilute alkalies. Thus, the predominance by humic acid fraction 1 can be considered one of the specific characteristics of brown forest soil humus.

The principal specific characteristic of the humus composition of the podzolized brown forest soils of the Kodry is the predominance of fraction 1 of the humic acids, which puts these soils in the same group with the brown forest soils of other regions (Table 4). The podzolized brown forest soils differ somewhat from the non-podzolized in the quantitative humus content and chiefly in the pattern by which the humus is distributed along the profile. Whereas the humus content of non-podzolized brown forest soils decreases gradually with depth, that of the podzolized brown forest soils decreases more conspicuously (Table 3). In soils under crops the humus content is cut off sharply.

The podzolized brown forest soils of the Kodry are highly saturated with adsorbed cations, 85 to 97% of saturation. Both the adsorbed cation content and the pattern of its distribution along the profile differ noticeably, depending on soil texture. Thus, the total adsorbed

TABLE 4

Composition of podzolized brown forest soil humus by groups and fractions
(Analysis by K. I. Kurilko)

Profile	Depth, cm.	Carbon in original soil, %	As % of total organic carbon in original soil								
			Humic acid C			Fulvic acid C			Bitumen C	Residual C	Humic acid C / Fulvic acid C
			Fraction 1	Fraction 2	Total	Fraction 1	Fraction 2	Total			
102 K	1–3	3.4	23.7	9.8	33.5	24.0	3.9	27.9	3.6	27.3	1.2
	21–31	0.9	20.2	12.8	33.0	30.9	5.3	36.2	6.4	14.9	0.9

Ca + Mg in the upper horizon of clay loam and fine clay loam reaches 27 to 40 me. per 100 gm. of soil and decreases gradually with depth (Table 3). In coarse clay loams the total adsorbed cations reach 10.4 to 11.6 me. and increase with depth. A decrease in the total Ca + Mg is rarely encountered at depths between 20 and 30 cm. Because of their high degree of saturation with exchangeable cations these soils have a weakly acid reaction. It is rare that saline suspensions have a pH of 5.5 to 4.3, and then chiefly only in the lower horizons.

Evaluation of the Brown Forest Soils of the Kodry from the Standpoint of Agricultural Production

Brown forest soils are the best soils for perennial plants. High-quality broad-leaved forests of rich composition grow on them. Considerable areas of these soils are used for gardens and vineyards. Because they have good physical and physicochemical properties, they assure a fairly high supply of nutrients. One of the specific characteristics of the brown Kodry forest soils is the relatively high nitrogen content in the humus. The total nitrogen content is 0.10 to 0.37%. The content of hydrolyzable nitrogen is 3.1 to 14.0 mg. per 100 gm. of soil, which amounts to about 2 to 4.5% of the total nitrogen. When brown forest soils are used in agriculture the nitrogen content decreases considerably because of the loss of humus. Thus, one of the basic measures for raising the fertility of these soils should be to fertilize them with organic or organomineral fertilizers.

Intensive accumulation of phosphorus is observed in brown forest soils. The total phosphorus content (as P_2O_5) is 0.53 to 0.65% of the ignited soil. These soils also have a good supply of available forms of phosphorus (Table 5).

Because of the wide development of erosion in the Kodry, considerable areas of brown forest

TABLE 5

Phosphorus, nitrogen and potassium content of brown forest soils

(Analysis by K. I. Kurilko and L. T. Biryukov)

Profile No.	Type of area	Depth of sample, cm.	Phosphorus		Nitrogen		Available potassium (K_2O), mg. per 100 gm. of soil
			Total, %	Available, mg. per 100 gm. of soil	Total, %	Hydrolyzable, mg. per 100 gm. of soil	
102 K	Forest	1–9	—	14.7	0.24	6.0	61.7
		10–19	—	6.4	0.23	4.9	46.8
		21–31	—	3.5	0.10	3.1	34.0
		Saturated brown forest soils					
1132	Plowland	5–15	0.65	4.6	0.08	8.9	17.2
		30–40	—	4.5	0.04	3.6	16.2
1133	Plowland	2–12	0.53	3.7	0.13	9.3	16.7
		13–23	0.59	2.9	0.08	6.3	13.3
42 M	Forest	4–10	—	9.8	0.33	9.6	22.1
		12–22	—	4.1	0.22	5.9	17.0
		23–33	—	7.6	0.19	5.0	15.0
		Podzolized brown forest soils					
42 K	Plowland	5–15	—	—	0.09	4.6	30.4
		30–40	—	—	0.06	3.2	—
		50–60	—	—	0.04	2.8	—
2 M	Plowland	5–15	—	9.3	0.21	6.6	13.0
		20–28	—	7.5	0.19	4.9	—

Note: available phosphorus was determined by Truog's method.

ils used for agricultural production have sufered losses from erosion. In the Kodry, erosion ntrol is one of the chief objectives for raising il fertility.

Conclusions

1. The specific characteristics of the plant over, climate and relief of the Kodry in which resembles the natural conditions of western uropean countries (Roumania, Bulgaria, and o forth) have left their impression on the soil over. The principal soil-forming tendency here of the brown-earth type, with formation redominantly of podzolized brown forest soils. ray forest soils and chernozems are associated ith the eastern and peripheral parts of the odry.

2. A typical characteristic of brown forest oils of the Kodry, as of all brown forest soils n warm, moist climates in piedmont or plains egions, is their considerable thickness. Here, he stratum of parent material involved in soil ormation is always considerably greater when rown forest soils are formed than when gray orest soils are formed, probably because of the reater age of the former.

3. One of the basic genetic characteristics of rown forest soils is the simultaneous combinaon in them of two opposing processes: podolization, with eluviation of alkaline earth etals and sesquioxides on the one hand, and he energetic formation of clay, with the acumulation of these substances as secondary inerals. The predominance of clay formation ver podzolization is a specific characteristic of hese soils. Energetic clay formation takes place oth because of weathering within the soil and lso as a result of biological processes.

4. Formation of the illuvial horizon in podolized brown forest soils takes place principally t the expense of iron. Aluminum has proved o be less mobile and accumulates in the upper art of the profile.

5. The energetic formation of clay in the prole and the high degree of biological accumulaon of adsorbed cations cause one more spefic characteristic of brown forest soils: the igh extent of saturation with cations.

6. Brown forest soils are the best soils for rowing broad-leaved forests and for gardens nd vineyards.

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TEXTURE OF ALLUVIAL SOIL AS RELATED TO THE DEVELOPMENT OF A FLOOD PLAIN

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VIL'YAMS (1) showed that depending on the quality and quantity of alluvium, two types of flood plain formation might occur. The so-called stratified flood plain forms when large quantities of coarse sandy alluvium are laid down. Granular flood plain forms when clayey alluvium is laid down. Vil'yams considered these types of flood plain to be stages of development in time, and that granular clay flood plains represent the first stage, with stratified flood plains following. Behind this idea is the thought that the texture of alluvium, and soils formed from it, indicates the type of flood plain, that is, the hydrodynamic conditions under which the material was deposited.

In further investigations of Plyusnin (3), and also in other works, it was shown that these ypes of flood plain should be considered not only as stages of development in time, but also n space, since stratified sandy flood plains appear near river channels, and granular ones appear centrally in the flood plain.

In the meandering river channel, there is always a constant mixing by flood waters of the central flood plain with that along the channel, and a consequent mixing of alluvium of different textures. This gave Lavrov (2), in agreement with geologists, a basis for distinguishing transgressive and regressive alluvial layers in the flood plain.

Thus, study of flood plain soil texture discloses some features of its formation, especially earlier meandering of the river channel.

We attempted to establish, if only to a first approximation, the quantitative expression of such connections. We obtained the following data upon investigating the middle and lower course of the Oka River.

Each region of the flood plain, as shown in Table 1, is specifically characterized by its flood water regime.

In going from the river channel to the flood plain, a sharp reduction in water speed is observed (as much as 1.15 meters per second). This causes the main mass of particles to settle out of the suspension in flood plain areas near the river channel. The thickness of alluvium deposited after one flood on the near channel flood plain amounts to 3 to 7 cm., that is the average rate of deposition equals about 1 cm. per day. In the central and near-terrace flood plains, the flood water becomes clear, its speed decreases still more, and in the last half of the flooding period it practically stands still. The decrease in speed causes sedimentation of those particles which still remain suspended in the flood water. In these areas of the flood plain, the annual thickness of alluvium is about 1 cm., that is, the average deposition rate is less than 0.66 mm. per day. Thus, we see a definite and significant quantitative difference between alluvial deposition in the near channel, central, and near terrace regions of the flood plain.

From a number of texture determinations of Oka flood plain soils[1] and alluvia, the most typical of which are presented in Table 2, the following characteristics appear. In the near channel flood plain, predominance of the fine sand fraction (0.25 to 0.05 mm. in diameter) is typical. The content of this fraction is 60 to 80% and often reaches 90%. The content of the clay fraction ($<$0.001 mm. in diameter) is very insignificant, lying between 1 and 10%. Often in the near channel flood plain a significant content (up to 40%) of the 1 to 0.25 mm. fraction (medium sand) is noted. Even in this case, the fine sand fraction predominates (50 to 60%). Usually, alluvia and soils of the near channel flood plains are sandy in texture.

We divided the central flood plain into ridges and flats according to their geomorphological characteristics. The ridges of the central flood plain appear to be transitional regions. In themselves they combine marks of the near channel flood plain (some ridges appear to be former channel banks left by the river in its meandering on the flood plain), and the central flood plain. On the basis of alluvium character and

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[1] 115 textures were determined on soils and alluvia of the Oka flood plain.

TABLE 1

Time of flooding and flow rate of high water on various flood plain regions and in the river channel (Polov, Ryazan district)

Characteristic	Channel	Flood plain region		
		Near channel	Central	Near terrace
Days of flooding	—	3–5	>13	>15
Flow rate of water (meters/sec.)	1.200–1.600	0.400–0.450	0.100–0.200	0.100–0.200

flooding regime, the ridges must be classed as central flood plain. The ridge flood plain lies between the near channel and flat flood plain, into which it gradually transforms. The border with the near channel flood plain is sharply developed.

In the flat central flood plain, the coarse silt fraction (0.05 to 0.01 mm. in diameter) predominates. It replaces the fine sand fraction (0.25 to 0.05 mm. in diameter), and is reciprocally related to it. The amount of clay fraction (<0.001 mm. in diameter) is approximately equal to that of the coarse silt fraction.

In going toward the river channel and in the gradual transition from flats to ridges, the fine sand content, typical for the near channel flood plain, increases more and more in alluvia and soils, while the content of the coarse silt fraction decreases. In texture, the alluvia and soils of the ridges are coarse and medium clay loams, and those of the flats are fine clay loams and coarse clays. The fine-texture characterizes alluvia and soils of the near terrace flood plain. The largest contents of the clay (up to 60%) and fine silt fractions (0.005 to 0.001 mm. in diameter—up to 30%) are found there. The content of physical clays increases to 95%.

TABLE 2

Texture of soils and alluvia of the Oka flood plain (pipette method of N. A. Kachinsk)

Sample number, soil description, and flood plain region	Horizon and depth of sampling, cm.	Percentage of particles in size fractions, mm.						
		1–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	<0.01
9. Weakly developed sod with buried meadow-sod soil at a depth of 130 cm. Near channel flood plain	A 3–12	trace	55.95	18.11	5.80	6.44	13.70	25.94
	I 25–35	"	81.80	6.27	2.51	2.60	6.82	11.93
	II 50–60	"	80.51	10.05	2.07	2.07	5.30	9.44
	III 80–90	"	84.39	3.14	1.07	0.72	10.68	12.47
	bs[a] 130–140	"	56.69	22.41	4.92	8.58	7.40	20.90
8. Sod with buried meadow-sod soil at a depth of 70 cm. Ridge flood plain	A 0–5	0.65	47.06	27.24	3.30	5.92	15.83	25.05
	A 5–15	0.52	49.60	25.05	2.99	5.44	16.40	24.83
	I 30–40	0.15	68.71	14.89	1.47	3.44	11.34	16.25
	bs[a] 70–80	0.23	19.58	35.40	4.89	11.25	28.65	44.79
	III 130–140	0.17	5.07	34.60	9.26	14.42	36.48	60.16
5. Meadow soil. Flat central flood plain	A′ 5–15	none	9.95	30.43	10.07	17.77	31.78	59.62
	A″ 35–45	"	13.36	28.84	8.16	18.70	30.94	57.80
	B 75–85	"	13.13	26.35	10.77	18.72	31.03	60.52
	B 120–130	"	21.92	26.29	9.21	13.91	28.67	51.79
556. Meadow-marsh soil. Near terrace flood plain	A 1–11	"	none	6.33	12.11	29.08	52.48	93.67
	A 18–28	"	0.85	5.15	12.28	24.12	57.60	94.00

[a] bs—buried soil

We attempted to analyze sample 8 (Table 2), a sod soil with a texture characteristic of the ridge flood plain (predominance of fine sand and notable content of coarse silt). The presence of a buried soil at a depth of 60 cm. testifies to a sharp change in the flooding regime sometime previously, while the texture of the buried soil and alluvium underneath show that here a regime of flat flood plain changed to one of near channel flood plain. The latter in turn changed to a regime nearly like a central flood plain (combined ridge-central flood plain). The alluvium thickness[2] indicates that the soil was buried about 40 to 60 years ago, and the new

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[2] Ad 0–5 cm., A 5–20 cm., I 20–60 cm.

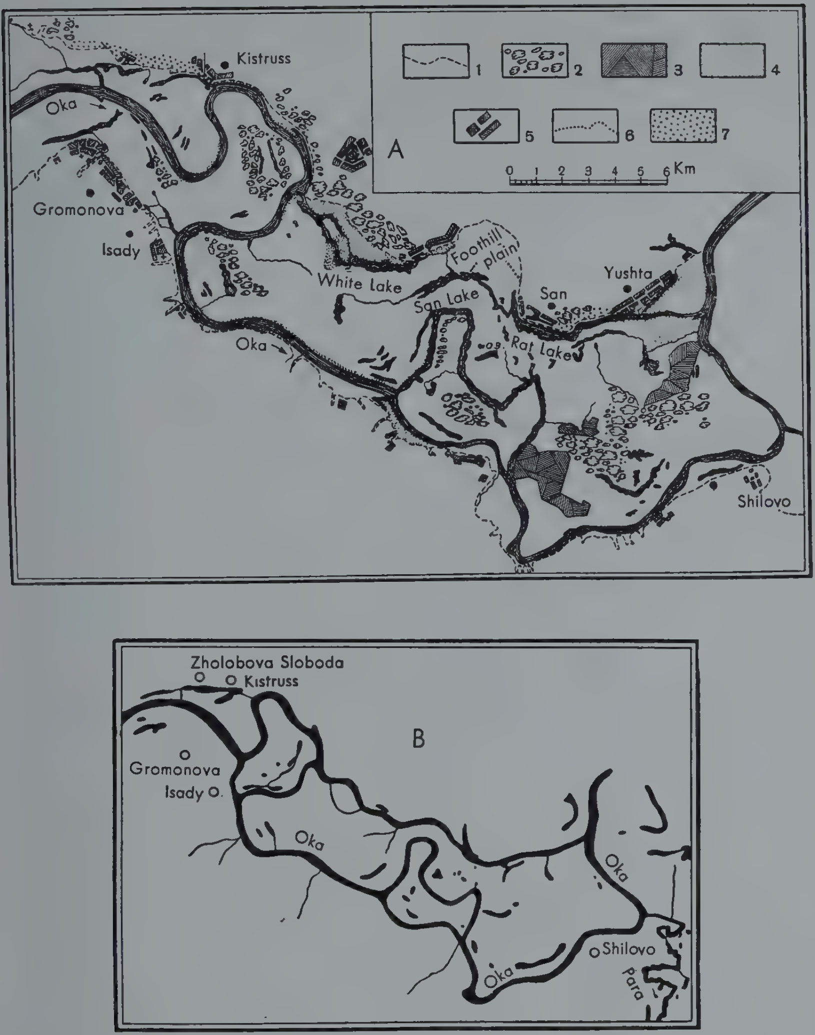

FIG. 1.—Part of the Oka flood plain among the villages of Kistruss, San, and Shilovo: A—According to an 1879 map; B—its present status. 1—border of the flood plain; 2—forest; 3—gardens; 4—sands; 5—inhabited points; 6—present border of weakly developed sod soils; 7—dunes.

hannel movement, with the emergence of this egion from a near channel regime, about 20 ears ago. Naturally, these figures are approxiate, but the possibility of such calculations s confirmed by examination of archives.

In the Ryazan regional museum we located ome maps, indicating changes in the position f the Oka river on its flood plain. Comparisons f these maps with present ones (see Figs. 1, A and B) showed that the "key" channel was formed in the early 1900's by the breakthrough of a chain of near terrace lakes (San, Rat, and so forth). The position of the river before this breakthrough is illustrated on the 1879 map (Fig. 1, A). In place of the present powerful stream, which conducts 25 to 35% of the water discharge, there was at that time only a chain of lakes.

On the basis of this data, we conclude that from the texture of flood plain soils and alluvia we can correctly distinguish flood plain regions, and also determine the history of formation of given layers of alluvium and changes in the flooding regime, that is, meandering of the stream channel on the flood plain. We can date this meandering by the alluvium thickness. The percentage content of the 0.25 to 0.05 mm. fraction characterizes the intensity of hydronamic processes in flooding. The greater this fraction, the greater the intensity, and the more the flooding regime belongs to the near channel type. Opposed to this is the content of the 0.05 to 0.01 mm. particle diameters, typical for central flood plains. By their ratios, we may decide how close the alluvial deposition is to the river channel, and its position among th flood plain regions. In particular, for Oka Rive conditions, ratios of the 0.20 to 0.05 mm. fra tion and the 0.05 to 0.01 mm. fraction equ to 1:4 or 1:2 are typical for flat central floo plain, a ratio 2:1 for ridge flood plain, an ratios from 4:1 to 70:1 for near channel floo plains.

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Reviews

SOIL GEOGRAPHY AND PRINCIPLES OF SOIL SCIENCE

A. Monin

A textbook of soil geography and fundamentals of soil science, in strict conformity with the llabus of the course taught by the Geographical culties of the Institute of Pedagogy, has not een available until the present. Even our far om perfect textbook[1], which was prepared for dents of the Cartographic Faculty of the In- tute of Geodetics (whose curriculum is similar that of the pedagogical institutes) did not meet e required standards.

The value of the book is further increased be- use a new course in the fundamentals of agri- lture has recently been introduced at the Nat- al Sciences-Geographical Faculties, for which knowledge of the principles of soil sciences is a cessary prerequisite.

The textbook of S. A. Monin has many unques- nable merits. It harmonizes with the curricu- m of the course in overall content as well as in dividual parts and chapters. It is well written, rictly scientific, but, at the same time is com- ehensible by students of Pedagogical Institutes. me of the terminology and concepts are ex- ained in the footnotes. The book is well illus- ated with drawings, diagrams, copies of maps d photographs. Soil maps of USSR and of the orld are separately enclosed (in colors).

However, despite the book's merits we find it cessary to call attention to several drawbacks, ginning with remarks of a general character.

The title, "Soil Geography and Principles Soil Science", does not agree with the contents. e reader will find here neither the geographic ttern of soil distribution nor a description of e soil cover of the individual areas of the USSR.

While stating correctly that the process of soil rmation and its result—the soil—are excellent ustrations of the soundness of dialectic materialism, the author is obviously carried away in his desire to explain everything in these terms. In five pages alone (11–15) he reiterates 11 times the unity of opposites, conflict of opposites, dialectic contradictions, and so forth. The soil composition of three phases—solid, liquid, and gaseous—the presence of mineral and organic particles in its solid phase, and the upward and downward movement of soil solution represent to the author the unity of dialectic opposites. However, solid substances change into a solution, or precipitate; organic and mineral compounds form organic-mineral complexes, and solutions move in all directions (including the horizontal), in accordance with the general laws of physics and chemistry. All these things are by no means specific to soil processes alone. Least of all do they illustrate the dialectic nature of soil formation, which consists (and in this respect the author is correct) of the synthesis and breakdown of organic substances.

After giving an account of different and sometimes contradictory opinions, the author either does not take a stand or he tries to reconcile them saying that it is possible to have one or the other under different conditions and at different times. This happens when he speaks of agricultural systems (V. R. Vil'yams and T. S. Mal'tsev; pp. 96–97), the genesis of gray forest soil (S. I. Korzhinskiy, V. R. Vil'yams, G. E. Grosset, V. V. Dokuchayev; pp. 176–178), and genetic interrelationships of salinized soils (K. K. Gedroits, V. R. Vil'yams; pp. 227).

The most essential remarks on individual points are these:

1. The author sketches the denitrification process as follows: nitric acid → nitrous acid → free, elementary nitrogen → ammonia (p. 33). It is impossible to understand how the author visualises the formation of ammonia from the free ni-

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[1] S. I. Sokolov. 1940. Short course of soil science. oscow.

trogen. And yet, this process is technologically feasible with the expenditure of energy. The perplexity deepens since the words "complete denitrification" follow "elementary nitrogen" in parentheses. This is not a misprint since it is repeated on page 159.

2. Soil structure is discussed in two chapters—IV "Physical Properties of Soils" and VII "Genesis and Classification of Soils", part of "Morphological Properties of Soils". This duplication is very characteristic and it reflects, unfortunately the mixture of different concepts still prevalent in our science. We have long insisted on clarifying the concept of soil structure, suggesting retention of the term "structure" for water-stable, agronomically valuable, granulated and closely related structures, and use of the term "pseudostructure" or "false structure" for non-water-stable, agronomically valueless and even harmful, prismatic, columnar, platy, and the like structures.

3. The author made several errors. Among the structureless formations he includes, besides sands, only cemented layers of ortstein and ortsand (pp. 39–40), forgetting that most of sedimentary clay, and especially, loess-like parent materials, and also soils of the desert zone, are structureless, if we do not speak of microstructure.

4. The chapter on physical properties of the soil cites the erroneous, unverified opinion of V. R. Vil'yams that the structural soil absorbs 85% of the precipitation, whereas structureless soil absorbs no more than 30%. Yet structureless sandy soils can absorb 100% of the precipitation.

5. The footnote on page 57 is completely puzzling: "pH is a concrete value, showing how many grams of H^+ are contained in one liter of a solution." An inexperienced reader will understand this to mean that for example, at pH4, one liter of solution will contain 4 gm. of hydrogen ions.

6. The statement that the pulverizing action of sodium ions on the arid desert steppe soils causes the formation of dust storms, hazes, and tornadoes is erroneous (p. 68). On the contrary, it is mainly the microaggregated soils saturated with calcium ions that are subject to weathering, and, under arid conditions, when saturated with sodium ions, they form a compact mass, or break up into columns and clods that the wind cannot disintegrate.

7. At the beginning of Chapter VII, while speaking of the general scheme of soil development and of the structural types of soil prof (pp. 70–75), the author completely accepts o system of letter designations of the genetic s horizons[2], although with no reference to t source taken. The diagrams shown in figures and 16 are graphic and convincing. Late strangely enough, the author forgets all about and for the rest of the text uses without qualific tion the old, but still generally used, symbols B, and C.

8. In the chapter on the tundra zone, the a thor at first states that "some particular tundra soils are non-existent. This is not true and do not agree with the data now available. Moreove a few lines below the author speaks of polygon soils as representing the "original surface formation characteristic of the northern tundra subzone." (page 133–134)

9. The podzol formation process is treated i accordance with R. V. Vil'yams scheme (pag 145–46), which is now scarcely acceptable in th form set forth 40 years ago, even to the mos orthodox followers of this scientist[3]. Using suc terms as crenic acid, crenates, and apocrenate the author contradicts himself, as in the sectio "Humus" (pp. 36–37) where he maintains completely different, modern point of view o humic substances. The text states that A. A Rode, N. P. Remezov, and S. P. Yarkov made further contribution to the theory of podzol formation, but there is no word about their idea Nor is there even a mention of another eminen scientist, K. K. Gedroits, and his valuable contribution to understanding the nature of podzo formation.

10. The classification of bog soils suggested b the author appears strange (pp. 160–2). Instea of the generally used and completely rational division into peat-bog and muck-bog (upper an lowland bog) the author divides them into peat bog and meadow-bog soils, and only whe subdividing the latter does he use the term "muck-bog" in parentheses as a synonym fo "humic-gley." Yet, by virtue of the intrinsi

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[2] S. I. Sokolov. 1938. Rational nomenclature o genetic soil horizons. Pochvovedeniye No. 6.

[3] In particular, the statement that properties o podzols are due to the accumulation of amorphou silicic acid, whereas K. D. Glinkoy followed by K K. Gedroits, A. A. Rode, and others establishe some time ago that silicic acid in the process of podzol formation is carried outside the soil profile. I this lies the main difference between a podzol an solodi.

anings of the words, the term "meadow-bog" uld be used for the transitional forms between meadow and bog soils—the so called "half- soils."

1. The statement of the author that a shallow ter table is beneficial for the development of est vegetation in the forest-steppe zone is with- foundation (p. 172). On the contrary, with broken relief of the greater part of the forest- ppe territory the ground waters are usually p.

2. The nut-like structure of the gray forest ls is characteristic of the accumulative-eluvial rizon, and not of the illuvial, as the author tes (p. 173). The illuvial horizon usually has rism-like structure.

13. It is primarily the presence of a colloidal- vial horizon, and not only siliceous grains (p. 4) that characterizes podzolic chernozem soils.

14. The term "meadow chernozems" (p. 194 elsewhere) which the author introduces in- ad of the term "meadow-chernozem" soils is apt. The first contains internal contradictions, ile the second accurately reflects the transi- nal character of these soils.

15. The inclusion of desert-steppe brown soils the desert zone, where all sierozems are also uped (p. 205), is not justified.

16. The statement that brown soils are char- terized by a uniform vertical profile (p. 208) not correct. The following lines which discuss compactness and prism-like characteristics of rizon B refute it.

17. The diagram of the solonchak formation neme (fig. 48, p. 219) resembles ours, (S. I. Sokolov "Short Course on Soil Science", fig. 8, p. 121) but is incomplete.

18. The gray forest soils belt is omitted from the description of vertical zonality in the Western Caucasus area (p. 250).

19. It was scarcely necessary to set aside a separate chapter for river-bottom land soils and to devote much more space to them than to the soils of the desert and chestnut zones (pp. 256–269). The structure of the river bottom lands is explained according to V. R. Vil'yams and with a repetition of the errors in his views, particularly the contention that the formation of river banks is due to the action of daily breezes.

One more observation of general character concerning the format of the book. The author cites the sources of the photos and drawings used in his book in only a few cases. Yet, drawings without a reference to the source are plainly not all original. For example, fig. 9, p. 58, is exactly the same as that found in "Soils, Their Properties and Distribution", fig. 23, p. 72, by N. P. Remezov. The same is true of fig. 18, p. 80 (in N. P. Remezov, fig. 5, p. 41) by S. A. Zakharov. The photograph in fig. 29, p. 134, is in D. G. Vilenskiy's book ("Soil Science", fig. 33, p. 194), where the author V. Meynardus is also mentioned.

All this naturally prevents us from noting the original drawings of the author.

There are several other minor errors, which do not need to be mentioned, since all of our observations cannot change the general positive evaluation of S. A. Monin's book.

Its publication should definitely be welcomed with satisfaction by a large circle of readers.

Reviewed by S. I. Sokolov

MANUAL OF LABORATORY AND FIELD METHODS

N. I. Gorbunov and N. Ye. Bekarevich

In 1957 the Ukranian Scientific-Research Institute of Soil Science published two books: 1. "Methods of Soil Studies and Soil Planning for Collective farms, Machine and Tractor Stations, and State Farms of the Ukranian SSR" (by several authors), and 2. "Manual of Laboratory and Field Methods for Soil Studies at State and Collective Farms in the Ukranian SSR" (compiled by N. P. Krupskiy in collaboration with V. I. Bazovluk, A. R. Daych, A. Ya Demidiyenko, M. A. Kochkin, N. I. Laktionov, A. K. Lomakina, N. T. Sizonenko, A. T. Usovich, and A. I. Sherevliya).

These books are intended for soil scientists and agricultural chemists and constitute two parts of a textbook for soil cartographic research. They deal with soil fertility and make recommendations on how to increase it by the use of crop rotation, fertilizer, effective agricultural engineering, and erosion control and other meliorative measures. The group of Ukranian scientists assumed a responsible and heavy burden and prepared both books for the press in a short time. There are not many such manuals and they can be justly considered a good beginning. Although the manual is designed for specialists studying Ukranian soils, it can be used by argicultural chemists and soil scientists in other republics.

During the last three to four years several manuals were published on more or less the same subject. Reprinted were "Chemical Soil Analysis" by K. K. Gedroits (Collected works., Vol. II, 1955, with supplements by N. P. Remezov and L. Ye. Novorossova); "Agrochemical Methods of Soil Studies" edited by A. V. Sokolov, D. L. Askinaz, and I. P. Serdobol'skiy (printed twice); and the monographs "Chemical Analysis of the Soil" by Ye. V. Arinushkina, 1952, "Laboratory Manual of Agricultural chemistry" by A. V. Peterburgskiy, and "Principles of Modern Methods and Techniques for Laboratory Determination of Soil Physical Properties" by A. M. Vasil'yev, 1953. All these textbooks were designed for well-equipped research or university laboratories.

The manual by N. P. Krupskiy and associates has a different purpose. It sets forth principles and techniques for the most important analyses
used in soil cartographic studies. Methods of
termining the physical properties of soils are ci
together with methods of agricultural chemi
analysis. In many instances the description of
analysis is preceded by an outline of the reas
for it along with a discussion of possible appli
tion of the results obtained. Consideration is gi
to the planning of analytical studies, the limi
tions of various methods, and the standards
analysis under the conditions of a laboratory w
average equipment. In the manual, methods lo
in use are described together with some n
promising ones.

Errors and shortcomings are inevitable as the
is no experience in the compilation of such a ma
ual. Let us consider some of them. It seems to
that the authors should have paid more attenti
to the correct reading of analyses and the utiliz
tion of analytic data. Some types of analysis ha
not been commented on at all in this respect.
would have been desirable to show the read
with the help of tables and examples how
choose a method or type of analysis correspon
ing to a given problem and peculiarities of th
soils.

The authors of the Manual separate analys
into general and special ones. The general cat
gory include: determination of texture, bulk den
sity, maximal hygroscopicity, maximal molecula
water capacity, upper and lower limits of con
sistence, humus content, and composition of ad
sorbed cations. It seems to us that determinatio
of the pH value should be listed with the genera
analyses, whereas determination of the molecula
water capacity and the composition of adsorbe
bases should be listed with the special ones.

Some analyses are given in many variations.
is not always clear, however, which variatio
should be chosen and how one should be guide
in selecting one. Some of the variations are no
feasible for average laboratories, especially thos
at machine and tractor station laboratories. Fo
example, the zinc-uranyl method and the meth
ods of studying an adsorbing complex with th
use of alcohol are, together with other method
cited for sodium determination; but these meth
ods hardly would be used. The computatio

ethod of determining adsorbed sodium should t be recommended (p. 185). Nor should the oplet method of determining the pH be used as her more convenient methods are more popu- r. It is a rare laboratory that could use the larographic method to determine the Fe^{++}/Fe^{+++} stem. The method of determining the adsorp- on capacity of calcareous soils with the aid of dioactive calcium would hardly be used (p. 7). The method of eliminating all the salts and sorbed cations from the soil by a weak acid lution and then saturating the soil with barium pH7 is much more practical. This method is idely used at the V. V. Dokuchayev Soil Insti- te.

The reader should not be encouraged to de- rmine adsorption capacity by hygroscopic mois- re, as these values are dependent on many ctors. References made by the authors to par- ular studies have a special meaning of their vn (p. 19). We think that preliminary removal salts should have been recommended for de- rmining the hygroscopicity of salinized soils in- ead of merely indicating the desirability of this termination. It is regretted that in describing ptization of the soil by trituration there is no ference to the fact that only repeated tritura- on makes possible the peptization of such soils chernozem, or soils rich in sesquioxides. If this not done, as many experiments have shown, the sults of determining the clay fraction will be eatly underestimated. The popular N. I. Savi- ov method of aggregate analysis is for some ason not mentioned in describing the method dispersion-aggregate analysis. The aggregate alysis method of N. Ye. Bekarevich seems to us be quite promising for solonetz soils.

Methods of SO_4 determination were taken up too much detail. Two or three methods would ave been sufficient.

The introductory section on the reasons behind e analytical methods is, in some instances, too tailed (particle size analysis, determination of ygroscopic moisture, and so forth), and in hers, too brief. While this unevenness is justi- ed, it will create difficulties for the inexperienced vestigator in selecting a method and utilizing e results.

The Manual pays little attention to determina- on of the physical properties of the soil. Even the bibliography we find only one reference. his chapter should have been enlarged by stress- g the indispensability and means of making analyses, and by recommending the determination of such soil properties as swelling, consistency, stickiness, water capacity, permeability, and others. Some of these analyses are feasible in any laboratory, some can be determined under field conditions. We must emphasize that the physical properties of the soil are of great interest to collective farmers who, relying on their own experience, characterize the soil solely by its physical properties.

Simplified field methods should have received much more attention, for example, the quantitative determination of sulfates and chlorides for salinized soils, the qualitative alkaline reaction for solonetzes, and so forth. Unfortunately, we do not have a standard field laboratory, but a soil scientist can set up one himself, and the recommendations for this purpose would have been very useful.

All the analyses should have been divided, not only into special and general ones, but also into approximate and more exact ones. In view of the great number of required analyses and the methods of making them, those recommended as approximate and those recommended as more exact should have been indicated. This obviously makes it necessary to evaluate the methods critically. It is practicable to conduct mass analyses with rapid, simplified methods, and to use on some of the controls the more exact, even if more time consuming, methods. We recommend the Kappen-Krumin'sh method for the determination of adsorption capacity in non-calcareous soils, while part of the control determinations can be made by the total of exchange cations. The authors show correctly that particle size analysis can be sometimes limited to the determination of fractions < 0.01 mm. in diameter.

The Manual contains the normal analyses for one worker. However, in most cases, the loss of time for the preparatory stage is not indicated, and in some cases, it is not indicated for the final or accompanying operations. For example, 1.25 hour is alloted for the determination of humus using I. V. Tyurin's method, but the substantial amount of time spent in picking rootlets from the samples is not specified. There is no reference to the time needed for the pulverization of specimens, preparation of reagents, computations and paper work, repetition of analyses for control purposes, operations accompanying the main analysis, and so on. We call attention to these details because industrial organizations will demand the fulfillment of the schedule of analyses in accordance with the norms shown on the page 13 of the Manual. For more thorough investigations, the Manual should have given total chemical analyses, with references to special instructions and an indication of the cases where these methods must be used.

The foregoing remarks and observations do n alter our opinion that the Manual is a good i tial contribution by the Ukranian soil scienti and agricultural chemists. It would have be worthwhile to call a working conference to d cuss the book.

ME QUESTIONS IN STUDYING SOIL GENESIS N CONNECTION WITH I. P. GERASIMOV'S REVIEW OF “A EW WORK ON BULGARIAN MOUNTAIN-FOREST SOILS[1])

V. Zonn

CADEMICIAN I. P. Gerasimov favorably reviewed my small contribution to the study the genesis of mountain-forest soils in relation the forest types in Bulgaria. I am taking this portunity to express my gratitude for his inest in my work. Since most of the conclusions not meet with any objections on his part, it be assumed that he evaluated positively the ievements of Soviet soil science because in dying the mountain-forest soils of Bulgaria, methods used were developed in our country. ave in mind the biogeocoenotic approach, ich is based on the idea of continuity and the found interrelations of biological and geologi- factors[2] with the conditions of soil formation, totality of which determines the development soils.

greeing with all theoretical suppositions that nstitute the essence of the biogeocoenotic apach, I. P. Gerasimov emphasized that no modn soil scientist-geneticist or geographer can dif with interpretations of the soil proposed by us. the same time he points out that an explanan should have been given as to wherein lie the ilarities and differences between the biogeonotic approach and usual scientific principles contemporary soil science.

We thought that the conclusions based on origl, factual data which underline the rigid relanship between the main types of mountainest soils and the separate types of forest mations, were the best explanation. For exple, under spruce, despite their superficial remblance to the spruce of our Siberian forest ne, specific types of soils develop, depending to greatest degree on the character and speed organic litter decomposition and on the peliarities of the ash and nitrogen cycles.

Under the canopy of fir forests are formed own forest soils owing to the relatively great richment of fir litter with calcium and other ash substances and the rapidity of its decomposition. Retention in their organic matter of some properties characteristic of the soils of spruce forests indicates that in the past these soils developed under spruce.

In the soils under pine forests, the impoverishment of the litter in ash substances, retardation of its decomposition, and large content of acid, water-soluble organic substances, created conditions favorable for the development of the podzolic process and was responsible for classifying these soils with the brown-podzolic type that we found earlier in the Northern Caucasus.

The foregoing examples show that the biogeocoenotic approach resulted in a determination of the possible effect of main woody parent material and the types of forests formed by it on soil formation and the structure of genetically different types. In this case, the use of this approach was limited due to the excursionary character of the investigations, which also explains why only a few of the qualitative aspects of these differences were determined.

The biogeocoenotic approach is essentially for permanent investigations of the manifold interactions of forests with soils in order to determine the properties and the types of metabolism and energy in biogeocoenoses. It is known that such soils to the greatest degree reflect in their properties the effects of flora and fauna. This approach is naturally based on a utilization of all the methods of investigation developed not only by soil science, but also by other closely related disciplines (forestery, soil zoology, microbiology, and so on) supplemented by a study of the composition and properties of the flora and fauna and their “work” in vital activity. For this reason the biogeocoenotic approach represents nothing new in principle but is an extension of existing approaches to a comprehensive investigation of soil formation and the genesis of soils.

All this justifies our view that such a study of soils—as the components of biogeocoenoses—

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[1] Pochvovedeniye, 1958, No. 6.

[2] By “geological factors” we mean the mineral sis of soils.

is one of the most progressive expansions of V. V. Dokuchayev's teachings on the continuity of natural phenomena and processes and is aimed at determining the quantitative criteria characterizing them. Herein lies the similarity and the difference between the biogeocoenotic approach and the scientific principles of contemporary soil science.

All investigations involving use of the biogeocoenotic approach in some degree have yielded much new data, not only for the development of the principles of biogeocoenosis, but also for soil genesis. Aside from the work in this field done by the Institute of Forest independently and jointly with the Soil Institute in Dzhanybek, we should like to mention the very interesting study on a biogeocoenotic basis of the takyrs of Turkmenia, which was directed by V. A. Kovda.

The further development of such studies will undoubtedly assist in solving moot questions related to the genesis and classification of soils. In the present stage of studies on soil genesis and geography using only the comparative-geographical method, it is impossible to solve all of these questions since the method does not provide sufficient quantitative criteria for judging the soil development processes. In the application of this method, the subjectivity of the researcher plays some part in perceiving the phenomena and explaining their origins.

For example, I. P. Gerasimov disagrees with my classifying the soil under oak forest (profile 16) with the brown forest soils, and the soil from profile 19 with the leached chernozems. He would rather classify the first with the gray soils, and the second with the dark-gray forest soils. Sufficient data confirming the correctness of this and other judgments are neither available to me nor to I. P. Gerasimov. Therefore, disputes on this theme are superfluous until pertinent data are collected.

Another example is I. P. Gerasimov's statement that I fail to mention either the gray forest or the unusual degraded, cinnamon-brown soils described by him and I. N. Antipov-Karatayev in 1948 in Bulgaria. First of all, I must point out that on pages 9 and 10 I mention that they isolated such soils, while emphasizing on page 54 that we did not have the opportunity to become familiar with them. I do not deny that they have been isolated in Bulgaria. However, I would like to add that their genesis shoul thoroughly studied to ascertain the qualit differences between the processes occurrin them and other types of soils.

In this connection I should like to rem that notwithstanding the existence of cinnan brown soils characteristic of dry Mediterra conditions, no data is yet available on the p esses occurring in them, a situation that is sponsible for the great subjectivity in diagno them and determining their distribution. It se to us that their formation under such theo cally different bioclimatic conditions (as in Mediterranean and monsoon and Eastern Chi is at variance with the original explanation of genesis of this type of soil. It is difficult to im ine that the interaction of the biological and g logical factors of soil formation would be ident under such different conditions.

In order to establish the possible similari and differences in the formation and evolut of soils classified as cinnamon-brown forest so it is now urgently necessary to make a care study of the processes taking place in the Use of the biogeocoenotic approach, and not o of the comparative-geographic one, would be assistance in successfully solving similar co plicated questions.

Another example of subjectivity from the b geocoenotic point of view is the identificati e.g., in Eastern Siberia, of ferric soils as an dependent type, based on a possibile change the physical processes of translocation of s solutions in them. Here, too, data on the pro esses of interaction of forest vegetation with so under such unusual and little studied conditio of soil formation are insufficient to justify tre ing these soils as a separate type.

These examples show how important it is the present stage of enlarging and extending search on the soil of the USSR and other cou tries by Soviet scientists to utilize not only comparative-geographical approach, which basically qualitative, but also the biogeocoeno approach.

The use of both methods can contribute t greater knowledge of soil genesis, to a firm basis for identifying new types of soils, and elaboration of the principles underlying a ne natural classification of soils.

Chronicle

ORK OF THE KRASNODAR DIVISON OF THE ALL-UNION OCIETY OF SOIL SCIENTISTS

e. S. Blazhniy

HE Krasnodar Division of the All-Union Society of Soil Scientists was organized in e last half of 1956; its 28 members work in lustry, scientific research, and institutions of gher learning.

The following lectures and reports, besides e organizational problems, were presented at e general meetings of the Society:

1. Work of the Soil Detachment of the Krasdar territory Agricultural Administration. V. Zavitkov).
2. Methods of regulating soil nitrification ocesses. (P. Ye. Prostakov).
3. Soils of the "Blinov" collective farm, Ad- district, Krasnodar kray. (V. F. Val'kov).
4. All–Union conference on agricultural chemil methods of soil investigation. (Ye. S. Blazhniy d A. I. Simakin).
5. Plan for instruction in the selection of land rcels for orchards and vineyards in Krasnodar ritory. (V. F. Val'kov).

The last report was presented at an enlarged eting of the Society, where the fruit and ape growers from the territorial agricultural ministration and from the scientific research d industrial organizations of the territory were attendance.

The main purpose of the reports was to help al institutions in investigating soils of the ritory and in practical application of the rets of agricultural research. Also, members the Society gave direct help to industry and rticipated in the propagation of scientific inmation on soil science and agricultural chemry.

Soil scientists of the Agricultural Institute e. S. Blazhniy, N. Ye. Red'kin, Ye. V. Tonnozhenko, Yu. N. Bagrov and G. V. Zavitkov) 1957 conducted studies on soil suitability for fruit planting in two state farms close to Krasnodar and in the "Zarya" collective farm (Gul'kevichskiy district) and drew conclusions on the suitability of the territory investigated for fruit plantings.

A detailed soil survey was conducted on the "Komsomolets" collective farm, Pavlovsk district, on an area of about 9000 hectares, and on the fruit-vegetable experimental plant breeding station in the "stanitza" of Crimea (area of 500 hectares). Also, soil maps on a scale of 1:25,000 and 1:5000 were compiled.

Forty lectures on soil science were presented: twenty-six of them were given in courses on the fruit growing industry, which were organized for agronomists by the Institute of Agriculture; the rest were presented directly at the state and collective farms of the territory. Basic themes of the lectures were: selection of soils for orchards and vineyards, characteristics of local soils and means of increasing their fertility. Fifteen hundred people listened to the lectures. Lectures on the fruit growing industry were the most popular. Repeated four times a day, they were attended by about 1000 agronomists from the state and collective farms and machine and tractor stations of the territory.

Six lectures were presented each time on the theme: soils of the Krasnodar territory and their suitability for fruit and grape planting. About 100 men from those present at the lectures attended additional, special laboratory and field practice in soil science under the guidance of the soil scientists from the Agricultural Institute (time 24 hours). The practical work was so organized that when they completed it, the agronomists could take a direct part locally in choosing plots for orchards and vineyards.

During the past period soil scientists of the

Agricultural Institute prepared for the press five scientific works: "Soils of the Plain and of the Foothill-Steppe Part of the Krasnodar Territory" (Ye. S. Blazhniy), "Total and Available Phosphorus in the Chernozem Soils of Krasnodar Territory" (N. Ye. Red'kin), "Characteristics of the Solonetz Soils in the Lower Reaches of the Kuban River" (Ye. V. Tonkonozhenko) and others.

Agricultural chemists (A. I. Simakin, L. P. Chavyskaya, and others) delivered at courses for the chiefs of agrochemical laboratories, for secondary school teachers, and directors of winery laboratories, 28 lectures on plant nutrition, chemical composition of the soil, and fertilizer application; they also helped to organize agrochemical laboratories in two machine and tractor stations (Pavlovsk and Dinsk) and gave scientific and technical assistance in developing methods of applying fertilizer in two local state farms and in two districts of the territory (Pavlovsk and Plastunovsk); they took part in the work of the territorial commission for development of a fertilizer application system for territorial zones. Two popular scientific works we published.

In order to compile the soil maps and choo the plots for orchards and vineyards, a tea of soil scientists from the territorial agricultur administration, headed by V. F. Val'kov, i tensively studied the soil cover of Temryukski Slavyanskiy, Anapskiy, Adlerskiy and other di tricts of the territory. In the fall of 1957 a lar number of soil scientists of the territorial agr cultural administration were sent for two mont into the eastern districts of the Soviet Union take part in studies on waste lands and virg soils.

Soil scientists (Ye. S. Gitman and others) the Krasnodar division of the State Plannin Institute "Giprospiritvino" studied the so cover of large tracts in the Dagestan ASS that were set aside for the planting of vineyard Soil scientists (G. K. Fatus and others) of th All-Union Tobacco and Machorka Institut studied the effect of fungicides (used for tobacc plant diseases) on the soil of the state tobacc farms in the territory.

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